

# CHAPTER 1

## DPP 1.1

### Single Correct Answer Type

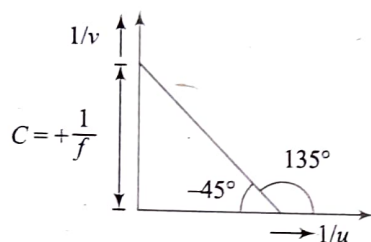
1. (a) Since  $\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$

Putting the sign convention properly

$$\frac{1}{(-v)} = \frac{-1}{(-u)} + \frac{1}{(-f)} \Rightarrow \frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$$

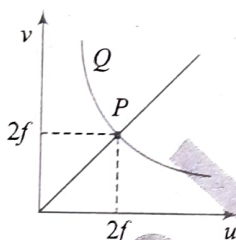
Comparing this equation with  $y = mx + c$

Slope  $= m = \tan \theta = -1 \Rightarrow \theta = 135^\circ$  or  $-45^\circ$  and intercept  $C = +\frac{1}{f}$



2. (c) As  $u \rightarrow f$ ,  $v \rightarrow \infty$ ;  $u \rightarrow \infty$ ,  $v \rightarrow f$

3. (c) At  $P$ ,  $u = v$  which happened only when  $u = 2f$   
At another point  $Q$  on the graph (above  $P$ )  
 $v > 2f$



4. (a) At  $u = f$ ,  $v = \infty$

At  $u = 0$ ,  $v = 0$  (i.e., object and image both lie at pole)

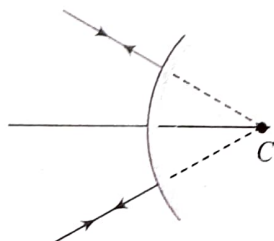
Satisfying these two conditions, only option (a) is correct.

5. (a) As  $u$  goes from 0 to  $\infty$ ,  $v$  goes from  $+0$  to  $+f$

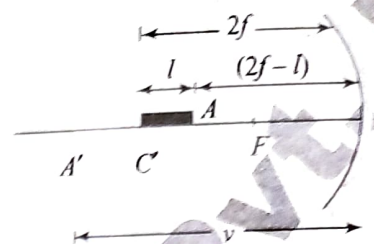
6. (c) Here object and image are at the same position so this position must be the centre of curvature

$$\therefore R = 12 \text{ cm}$$

$$\Rightarrow f = \frac{R}{2}$$



7. (b)



End  $A$  of the rod acts as an object for mirror and  $A'$  will be its image so  $u = 2f - l = 20 - 5 = 15 \text{ cm}$

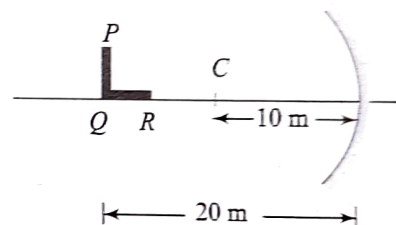
$$\therefore \frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{-10} = \frac{1}{v} + \frac{1}{15} \Rightarrow v = -30 \text{ cm}$$

$$\text{Now } m = \frac{\text{Length of image}}{\text{Length of object}} = \frac{(30 - 20)}{5} = 2$$

8. (a)  $m = \frac{I}{O} = \frac{f}{u - f} = \frac{10}{25 - 10} = \frac{10}{15} = \frac{2}{3}$

$$m^2 = \frac{A_i}{A_o} \Rightarrow A_i = m^2 \times A_o = \left(\frac{2}{3}\right)^2 \times (3)^2 = 4 \text{ cm}^2$$

9. (b) Focal length of mirror  $f = \frac{R}{2} = \frac{10}{2} = 5 \text{ cm}$



For part  $PQ$ : transverse magnification

$$\begin{aligned} \text{Length of image } L_1 &= \left(\frac{f}{f - u}\right) \times L_0 \\ &= \left(\frac{-5}{-5 - (-20)}\right) \times L_0 = \frac{-L_0}{3} \end{aligned}$$

For part  $QR$ : longitudinal magnification

$$\begin{aligned} \text{Length of image } L_2 &= \left(\frac{f}{f - u}\right)^2 L_0 \\ &= \left(\frac{-5}{-5 - (-20)}\right)^2 \times \frac{L_0}{9} \end{aligned}$$

$$\Rightarrow \frac{L_1}{L_2} = \frac{3}{1}$$

10. (d) For surface  $P$ ,  $\frac{1}{v_1} = \frac{1}{f} - \frac{1}{u} = 1 - \frac{1}{3} = \frac{2}{3} \Rightarrow v_1 = \frac{3}{2} \text{ m}$

For surface  $Q$ ,  $\frac{1}{v_2} = \frac{1}{f} - \frac{1}{u} = 1 - \frac{1}{5} = \frac{4}{5} \Rightarrow v_2 = \frac{5}{4} \text{ m}$

$$\therefore v_1 - v_2 = 0.25 \text{ m}$$

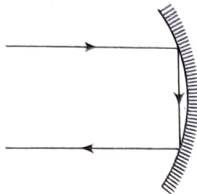
$$\text{Magnification of } P = \frac{v_1}{u} = \frac{3/2}{3} = \frac{1}{2}$$

$$\therefore \text{Height of } P = \frac{1}{2} \times 2 = 1 \text{ m}$$

$$\text{Magnification of } Q = \frac{v_2}{u} = \frac{5/4}{5} = \frac{1}{4}$$

$$\therefore \text{Height of } Q = \frac{1}{4} \times 2 = 0.5 \text{ m}$$

11. (b) The only possibility is by reflection from concave mirror as shown.



12. (c) As the object moves from infinity to centre of curvature, the distance between object and image reduces from infinity to zero. As the object moves from centre of curvature to focus, the distance between object and image increases from zero to infinity.

As the object moves from focus to pole, the distance between object and its image reduces from infinity to zero. Hence the distance between object and its image shall be 40 cm which is three times.

### Multiple Correct Answers Type

13. (a, c) For convex mirror

$$|m| < 1 \text{ for any real object}$$

$$\text{Now, } V_{\text{image}} = -m^2 V_{\text{object}}$$

$$\Rightarrow |V_{\text{image}}| < |V_{\text{object}}| \text{ always.}$$

14. (a, c) A concave or convex mirror is to be placed left of the object. The object and the image both will be real for concave mirror and virtual for convex mirror.

### Matching Column Type

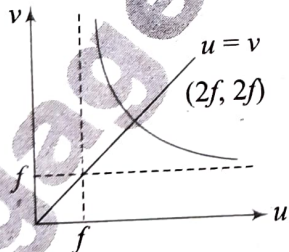
15. (A)  $\rightarrow$  Q; (B)  $\rightarrow$  P; (C)  $\rightarrow$  P; (D)  $\rightarrow$  S

$$\text{As } v = \infty \text{ for } u = f$$

$$\text{and } n = \infty \text{ for } v = f$$

The graph is hyperbola.

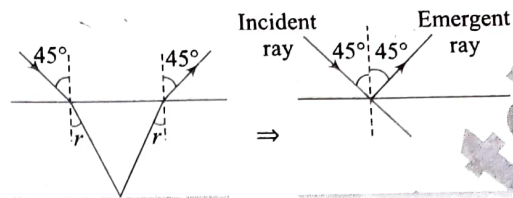
A line  $v = u$  will cut this hyperbola at  $(2f, 2f)$



## DPP 1.2

### Single Correct Answer Type

1. (a) From the figure it is clear that the angle between incident ray and the emergent ray is  $90^\circ$ .

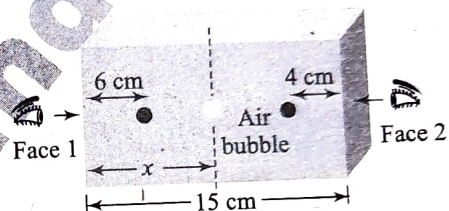


2. (a) Light ray is going from liquid (denser) to air (rarer) and angle of refraction is  $90^\circ$ , so the angle of incidence must be equal to critical angle from figure

$$\sin C = \frac{4}{5}$$

$$\text{Also } \mu = \frac{1}{\sin C} = \frac{5}{4} = 1.2$$

3. (d) When viewed from face (1)



$$\mu = \frac{u}{v} = \frac{x}{6} = \frac{x}{6} \quad (i)$$

Now when viewed from face (2)

$$\mu = \frac{15-x}{v} = \frac{15-x}{4} \quad (ii)$$

$$\text{From equation (i) and (ii) } \mu = \frac{15-6\mu}{4} \Rightarrow \mu = 1.5$$

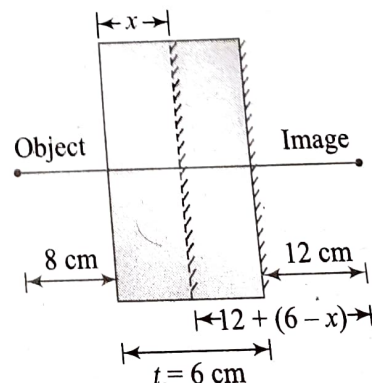
4. (b) Image formation by a mirror (either plane or spherical) does not depend on the medium. The image of  $P$  will be formed at a distance  $h$  below the mirror. If  $d$  = depth of liquid in the tank.

$$\text{Apparent depth of } P = x_1 = \frac{d-h}{\mu}$$

$$\text{Apparent depth of the image of } P = x_2 = \frac{d+h}{\mu}$$

$$\therefore \text{Apparent distance between } P \text{ and its image} = x_2 - x_1 = \frac{2h}{\mu}$$

5. (c) Let  $x$  be the apparent position of the silvered surface.



#### S.4 Optics and Modern Physics

According to property of plane mirror,

$$x + 8 = 12 + 6 - x \Rightarrow x = 5 \text{ cm}$$

$$\text{Also } \mu = \frac{t}{x} \Rightarrow \mu = \frac{6}{5} = 1.2$$

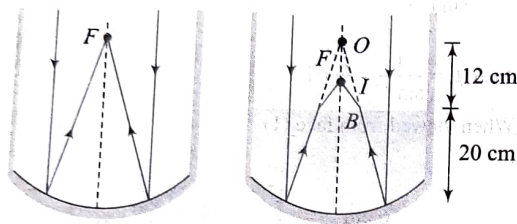
6. (b) Sun is at infinity, i.e.,  $u = \infty$  so from mirror formula we have

$$\frac{1}{f} = \frac{1}{-32} + \frac{1}{(-\infty)} \Rightarrow f = -32 \text{ cm}$$

When water is filled in the tank up to a height of 20 cm, the image formed by the mirror will act as virtual object for water surface, which will form its image at  $I$  such that

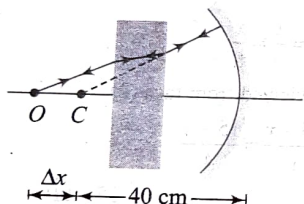
$$\frac{\text{Actual height}}{\text{Apparent height}} = \frac{\mu_w}{\mu_a} \text{ i.e., } \frac{BO}{BI} = \frac{4/3}{1}$$

$$\Rightarrow BI = BO \times \frac{3}{4} = 12 \times \frac{3}{4} = 9 \text{ cm}$$



7. (c)  $\Delta x = \left(1 - \frac{1}{\mu}\right)t = \left(1 - \frac{1}{1.5}\right) \times 6 = 2 \text{ cm}$

Distance of object from mirror = 42 cm

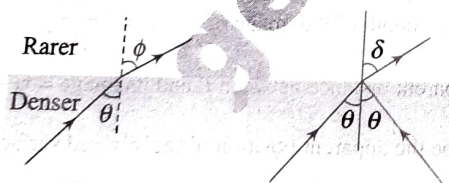


8. (c) When the ray passes into the rarer medium, the deviation is

$\delta = \phi - 0$ . This can have a maximum value of  $\left(\frac{\pi}{2} - C\right)$  for

$$\theta = C \text{ and } \phi = \frac{\pi}{2}.$$

When total internal reflection occurs, the deviation is  $\delta = \pi - 2$ , the minimum value of  $\theta$  being  $C$ . The maximum value of  $\delta = \pi - 2C$ .

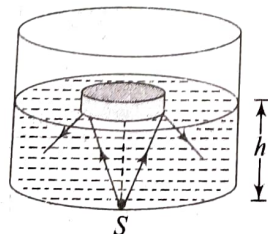


9. (c) Suppose the maximum height of the liquid is  $h$  for which the source is not visible.

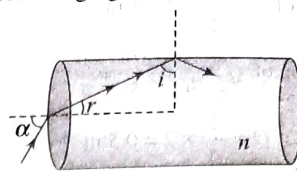
Hence radius of the disc

$$r = \frac{h}{\sqrt{\mu^2 - 1}}$$

$$1 = \frac{h}{\sqrt{\left(\frac{5}{3}\right)^2 - 1}} \Rightarrow h = 1.33 \text{ cm}$$



10. (a) From the following figure



$$r + i = 90^\circ \Rightarrow i = 90^\circ - r$$

For ray not to emerge from curved surface  $i > C$

$$\Rightarrow \sin i > \sin C \Rightarrow \sin(90^\circ - r) > \sin C \Rightarrow \cos r > \sin C$$

$$\Rightarrow \sqrt{1 - \sin^2 r} > \frac{1}{n} \quad \left\{ \because \sin C = \frac{1}{n} \right\}$$

$$\Rightarrow 1 - \frac{\sin^2 \alpha}{n^2} > \frac{1}{n^2} \Rightarrow 1 > \frac{1}{n^2} (1 + \sin^2 \alpha)$$

$$\Rightarrow n^2 > 1 + \sin^2 \alpha \Rightarrow n > \sqrt{2}$$

$$\{\sin i \rightarrow 1\}$$

$$\Rightarrow \text{Least value} = \sqrt{2}$$

11. (b) Here the requirement is that  $1 > c$

$$\Rightarrow \sin i > \sin c \Rightarrow \sin i > \frac{\mu_2}{\mu_1} \quad (i)$$

$$\text{From Snell's law } \mu_1 = \frac{\sin \alpha}{\sin r} \quad (ii)$$

Also in  $\triangle OBA$

$$r + i = 90^\circ \Rightarrow r = (90^\circ - i)$$

Hence from equation (ii)

$$\sin \alpha = \mu_1 \sin(90^\circ - i)$$

$$\Rightarrow \cos i = \frac{\sin \alpha}{\mu_1}$$

$$\sin i = \sqrt{1 - \cos^2 i} = \sqrt{1 - \left(\frac{\sin \alpha}{\mu_1}\right)^2} \quad (iii)$$

$$\text{From equations (i) and (iii), } \sqrt{1 - \left(\frac{\sin \alpha}{\mu_1}\right)^2} > \frac{\mu_2}{\mu_1}$$

$$\Rightarrow \sin^2 \alpha < (\mu_1^2 - \mu_2^2) \Rightarrow \sin \alpha < \sqrt{\mu_1^2 - \mu_2^2}$$

$$\alpha_{\max} = \sin^{-1} \sqrt{\mu_1^2 - \mu_2^2}$$

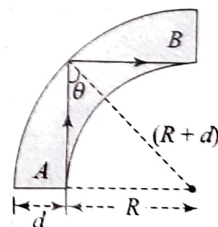
12. (b) Consider the figure if smallest angle of incidence  $\theta$  is greater than critical angle, then all light will emerge out of B

$$\Rightarrow \theta \geq \sin^{-1} \left( \frac{1}{\mu} \right) \Rightarrow \sin \theta \geq \frac{1}{\mu}$$

$$\text{From figure } \sin \theta = \frac{R}{R + d}$$

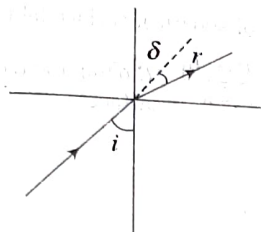
$$\Rightarrow \frac{R}{R + d} \geq \frac{1}{\mu} \Rightarrow \left(1 + \frac{d}{R}\right) \leq \mu$$

$$\Rightarrow \frac{d}{R} \leq \mu - 1 \Rightarrow \left(\frac{d}{R}\right)_{\max} = 0.5$$



13. (a) The ray of light is refracted at the plane surface.

However, since the ray is travelling from a denser to a rarer medium, for an angle of incidence ( $i$ ) greater than the critical angle ( $c$ ) the ray will be totally internally reflected.



For  $i < c$ ; deviation  $\delta = r - i$  with  $\frac{1}{\mu} = \frac{\sin i}{\sin r}$

Hence  $\delta = \sin^{-1}(\mu \sin i) - i$

This is a non-linear relation. The

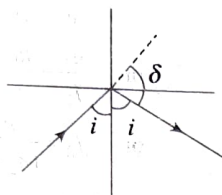
maximum value of  $\delta$  is  $\delta_1 = \frac{\pi}{2} - c$ ;

where  $i = c$  and  $\mu = \frac{1}{\sin c}$

For  $i > c$ , deviation  $\delta = \pi - 2i$

$\delta$  decreases linearly with  $i$

$\delta_2 = \pi - 2c = 2\delta_1$



14. (b) Apparent depth  $h' = \frac{h}{\mu_{\text{liquid}}}$

$$\Rightarrow \frac{dh'}{dt} = \frac{1}{\mu_w} = \frac{1}{\mu_w} \frac{dh}{dt}$$

$$\Rightarrow x = \frac{1}{\mu_w} \frac{dh}{dt} \Rightarrow \frac{dh}{dt} = \mu_w x$$

Now volume of water  $V = \pi R^2 h$

$$\begin{aligned} \Rightarrow \frac{dV}{dt} &= \pi R^2 \frac{dh}{dt} = \pi R^2 \cdot \mu_w x \\ &= \mu_w \pi R^2 x = \frac{\mu_w}{\mu_a} \pi R^2 x = \left( \frac{n_2}{n_1} \right) \pi R^2 x \end{aligned}$$

### Multiple Correct Answers Type

15. (b, c) From graph  $\tan 30^\circ = \frac{\sin r}{\sin i} = \frac{1}{\mu_2}$

$$\Rightarrow \mu_2 = \sqrt{3} \Rightarrow \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = 1.73 \Rightarrow v_1 = 1.73v_2$$

$$\text{Also from } \mu = \frac{1}{\sin i_c} \Rightarrow \sin i_c = \frac{1}{\mu} = \frac{1}{\mu_{\text{Denser}}}$$

$$\Rightarrow \sin i_c = \frac{1}{\mu_2} = \frac{1}{\sqrt{3}}$$

## DPP 1.3

### Subjective Type

1. For I<sup>st</sup> surface:  $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$$\frac{3/2}{v} - \frac{1}{\infty} = \frac{3/2 - 1}{+10} = \frac{1}{20}$$

$$v = 30 \text{ cm}$$

This will be the distance of the object for the second surface.

$$\text{For II<sup>nd</sup> surface: } \frac{4/3}{v'} - \frac{3/2}{+30} = \frac{4/3 - 3/2}{-10}$$

$$\frac{4}{3v'} - \frac{1}{20} = \frac{1}{60}$$

$$v' = +20 \text{ cm}$$

For III<sup>rd</sup> surface:  $u = 20 - 10 = 10$  and  $R = \infty$

$$\frac{1}{v''} - \frac{4/3}{+10} = \frac{\mu_2 - \mu_1}{\infty} = 0$$

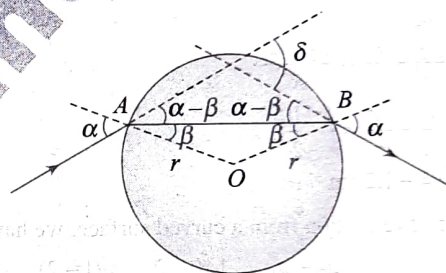
$$\frac{1}{v''} = \frac{4}{30} \Rightarrow v'' = \frac{30}{4}$$

The distance of final image from curved surface =  $10 + \frac{30}{4} + \frac{70}{4} = 17.5 \text{ cm}$

### Single Correct Answer Type

2. (b) From the following ray diagram it is clear that

$$\delta = (\alpha - \beta) + (\alpha - \beta) = 2(\alpha - \beta)$$

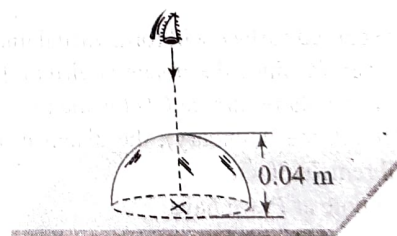


3. (a) By using formula  $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$$\Rightarrow \frac{1.5}{v} - \frac{1}{(-15)} = \frac{(1.5 - 1)}{+30} \Rightarrow v = -30 \text{ cm}$$

Negative sign shows that image is obtained on the same side of object, i.e., towards left.

4. (b) Case (i): When flat face is in contact with paper.



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \text{ where}$$

$\mu_2 = R$ . I. of medium in which light rays are going = 1

$\mu_1 = R$ . I. of medium from which light rays are coming = 1.6

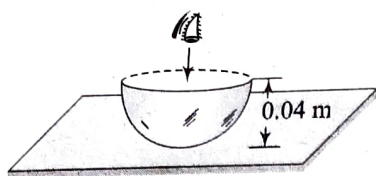
$u$  = distance of object from curved surface =  $-0.04 \text{ m}$

$R = -0.04 \text{ m}$

$$\therefore \frac{1}{v} - \frac{1.6}{(-0.04)} = \frac{1 - 1.6}{(-0.04)} \Rightarrow v = -0.04 \text{ m}$$

i.e., the image will be formed at the same position of cross.

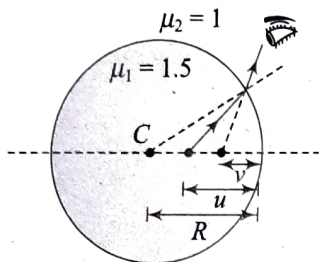
Case (ii): When curved face is in contact with paper



$$\mu = \frac{\text{Real depth } (h)}{\text{Apparent depth } (h')}$$

$$\Rightarrow 1.6 = \frac{0.04}{h'} \Rightarrow h' = 0.025 \text{ m} \quad (\text{Below the flat face})$$

5. (a)  $v = 1 \text{ cm}$ ,  $R = 2 \text{ cm}$



By using

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

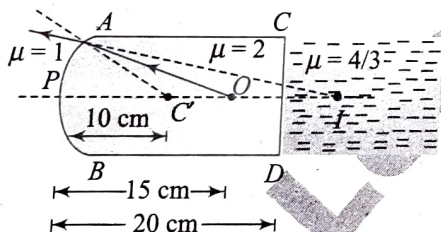
$$\frac{1}{-1} - \frac{1.5}{u} = \frac{1 - 1.5}{-2}$$

$$\Rightarrow u = -1.2 \text{ cm}$$

6. (b) In case of refraction from a curved surface, we have

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \Rightarrow \frac{1}{v} - \frac{2}{(-15)} = \frac{(1-2)}{-10}$$

$$\Rightarrow v = -30 \text{ cm}$$



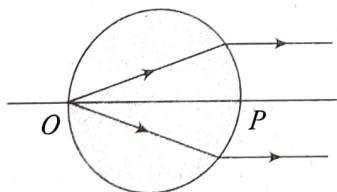
That is, the curved surface will form virtual image  $I$  at distance of 30 cm from  $P$ . Since the image is virtual, there will be no refraction at the plane surface  $CD$  (as the rays are not actually passing through the boundary), the distance of final image  $I$  from  $P$  will remain 30 cm.

7. (c) Considering pole at  $P$ , we have

$$\Rightarrow \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1}{\infty} - \frac{\mu}{(-2R)} = \frac{1 - \mu}{(-R)}$$

$$\Rightarrow \frac{\mu}{2R} = \frac{1 - \mu}{(-R)} \Rightarrow \mu = 2$$



(a) By using  $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$$\text{where } \mu_1 = \frac{4}{3}, \mu_2 = 1, u = -6 \text{ cm}, v = ?$$

On putting values  $v = -5.2 \text{ cm}$

9. (a) Using formula of spherical surface taking 'B' as object

$$\frac{\mu_2}{\infty} - \frac{\mu_1}{(-2R)} = \frac{\mu_2 - \mu_1}{-R} \quad (R \text{ being the radius of the curved surface})$$

$$\Rightarrow \frac{\mu_1}{\mu_2} = 2$$

### Multiple Correct Answers Type

10. (a, d)

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \quad (i)$$

$$\text{or } \frac{n_2}{f_2} - \frac{n_1}{\infty} = \frac{n_2 - n_1}{R}$$

$$\text{or } f_2 = \frac{n_2 R}{(n_2 - n_1)} \quad (ii)$$

Similarly,

$$\frac{n_2}{\infty} - \frac{n_1}{f_1} = \frac{n_2 - n_1}{R} \text{ will give}$$

$$f_1 = (-) \frac{n_1 R}{(n_2 - n_1)} \quad (iii)$$

### Comprehension Type

11. (b) For refraction at surface 1,

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u'} = \frac{\mu_2 - \mu_1}{R}$$

$$\text{Here } \mu_1 = 1, \mu_2 = 1.5$$

$$\mu' = -x \text{ and } R = 20 \text{ cm}$$

Putting these values,

$$\frac{1.5}{v'} + \frac{1}{x} = \frac{0.5}{20}$$

$$\Rightarrow \frac{3}{2v'} = \frac{1}{40} - \frac{1}{x} = \frac{x - 40}{40x}$$

$$\Rightarrow v' = \frac{60x}{(x - 40)}$$

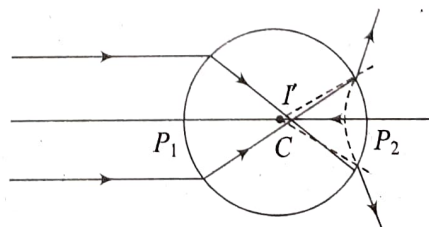
If the image formed by surface 1 is real, it must form to the right of  $P_1$ , i.e.,  $v' \geq 0$

Thus, using above equation, image formed by surface 1 is real if  $x \geq 40 \text{ cm}$  and virtual if  $x < 40 \text{ cm}$ .

Let  $I'$  be the image formed by surface 1 and  $I$  be the final image formed by surface 2.

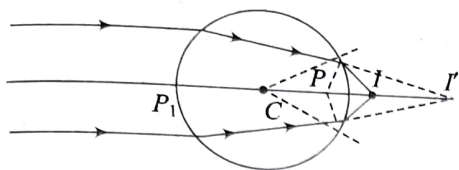
For refraction at surface 2, we have three possibilities.

In first case, image formed by surface 1 lies between  $C$  and  $P_2$ . Here,  $I'$  is the image formed by left surface. Obviously it is real. It acts as object for surface 2 which forms a final image  $I$ .



Thus the final image will be virtual in this case as shown in the diagram.

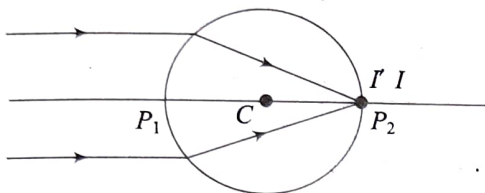
In the second case, image formed by left surface lies to right of  $P_2$ .



Here  $I'$  is the image formed by left surface. It acts as virtual object for the right surface, which forms a final image  $I$  that is real.

Thus the final image is real in this case.

In the third case, suppose the image formed by left surface lies at  $P_2$ .



If  $I'$  lies at  $P_2$  it will also be the final image and it is real.

To conclude, if  $I'$  lies between  $C$  and  $P_2$ , the final image is virtual and if  $I'$  lies at  $P_2$  or beyond  $P_2$  the final image is real.

Hence, for the final image  $I$  to be real, distance of  $I'$  from  $P_1$  which is  $v'$  should be greater than or equal to  $2R$ .

$\therefore$  For a final real image,  $v' \geq 2R$ , i.e.,  $v' \geq 40$  cm.

Invoking previous equation,  $v' = \frac{60x}{(x-40)} = \frac{60}{1 - \left(\frac{40}{x}\right)}$

Above equation proves that if  $x \geq 40$  cm, then  $v' \geq 60$  cm.

Thus, if the image formed by surface 1 is real then the image formed by surface 2 has to be real and this occurs for  $x \geq 40$  cm.

12. (a) Let us investigate the possibility that image formed by surface 1 is virtual, whereas the image formed by surface 2 is real. As is clarified by the explanation of previous question, above situation is possible only if  $x \leq 40$  cm. For  $x_2 < x < 40$  cm, the image formed by surface 1 is virtual. When  $x = x_2$ , image formed by surface 1 should be at distance  $R$  to the left of  $P_1$ . Thus, we apply the equation

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u'} = \frac{\mu_2 - \mu_1}{R}$$

$$\mu_1 = 1, \mu_2 = 1.5$$

Here,  $u' = -x_2$ , and  $v' = -20$  cm

Putting values,

$$\frac{1.5}{-20} + \frac{1}{x_2} = \frac{0.5}{20} \Rightarrow x_2 = 10 \text{ cm}$$

13. (b) The image formed by surface 1 acts as object for surface 2.

14. (b) If object is placed at  $x \rightarrow \infty$ , for refraction at surface 1,

$$\mu_1 = 1, \mu_2 = 1.5$$

$$u_1 = -\infty \text{ and } R = 20 \text{ cm}$$

$$\text{Applying } \frac{\mu_2}{v_1} - \frac{\mu_1}{u_1} = \frac{\mu_2 - \mu_1}{R}$$

We get  $v_1 = 60$  cm

Thus, for refraction at surface 2,

$$\mu_1 = 1.5, \mu_2 = 1$$

$$u_2 = 20 \text{ cm and } R = -20 \text{ cm}$$

Putting values in equation for refraction,  $\frac{1}{v_2} - \frac{1.5}{20} = \frac{-0.5}{-20}$

$$\frac{1}{v_2} = \frac{3}{40} + \frac{1}{40} = \frac{1}{10}$$

Thus, final image is formed 10 cm to the right of  $P_2$ .

15. (c) If object is placed at  $x \rightarrow \infty$  and refractive index of sphere is 2.5, for refraction at surface 1,

$$\mu_1 = 1, \mu_2 = 2.5$$

$$u_1 = -\infty \text{ and } R = 20 \text{ cm}$$

$$\text{Applying } \frac{\mu_2}{v_1} - \frac{\mu_1}{u_1} = \frac{\mu_2 - \mu_1}{R}$$

$$\text{We get } v_1 = \frac{100}{3} \text{ cm}$$

It lies at a distance  $40 - \frac{100}{3} = \frac{20}{3}$  cm to the left of  $P_1$ .

Thus, for refraction at surface 2,

$$\mu_1 = 2.5, \mu_2 = 1$$

$$u_2 = -20/3 \text{ cm and } R = -20 \text{ cm}$$

Putting values in equation for refraction,

$$\frac{1}{v_2} + \frac{2.5 \times 3}{20} = \frac{-1.5}{-20}$$

$$\frac{1}{v_2} = -\frac{15}{40} + \frac{3}{40} = -\frac{12}{40} = -\frac{3}{10}$$

$$\Rightarrow v_2 = -3.33 \text{ cm}$$

Thus, final image is formed 3.33 cm to the left of  $P_2$ .

## DPP 1.4

### Single Correct Answer Type

1. (d) For a lens  $m = \frac{f-v}{f} = -\frac{1}{f}v + 1$

Comparing it with  $y = mx + c$

$$\text{Slope} = m = -\frac{1}{f}$$

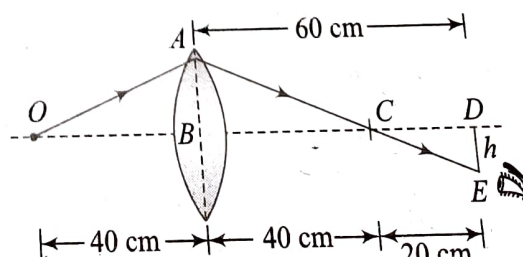
From graph, slope of the line =  $\frac{b}{c}$

$$\text{Hence } -\frac{1}{f} = \frac{b}{c} \Rightarrow |f| = \frac{c}{b}$$

2. (d) For a lens  $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

If  $u = \infty$ ,  $v = f$  and if  $u = f$ ,  $v = \infty$

3. (c) In the following ray diagram  $\Delta s ABC$  and  $CDE$  are symmetric

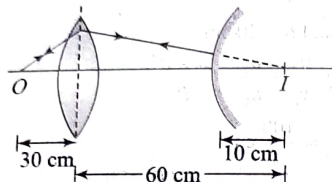


## S.8 Optics and Modern Physics

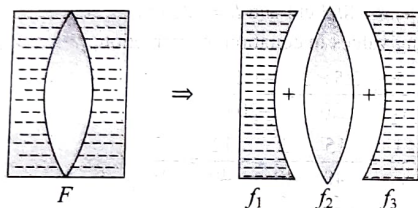
So,  $\frac{AB}{BC} = \frac{DE}{CD} \Rightarrow \frac{5}{40} = \frac{h}{20} \Rightarrow h = 2.5 \text{ cm}$

4. (c) For lens  $u = 30 \text{ cm}$ ,  $f = 20 \text{ cm}$ , hence by using  $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$   
 $\Rightarrow \frac{1}{+20} = \frac{1}{v} - \frac{1}{-30} \Rightarrow v = 60 \text{ cm}$

The final image will coincide the object, if light ray falls normally on convex mirror as shown. From the figure, it is seen clear that separation between lens and mirror is  $60 - 10 = 50 \text{ cm}$ .



5. (d)  $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$



$\frac{1}{f_1} = (1.6 - 1) \left( \frac{1}{\infty} - \frac{1}{20} \right) = -\frac{0.6}{20} = -\frac{3}{100}$  (i)

$\frac{1}{f_2} = (1.5 - 1) \left( \frac{1}{20} - \frac{1}{-20} \right) = \frac{1}{20}$  (ii)

$\frac{1}{f_3} = (1.6 - 1) \left( \frac{1}{-20} - \frac{1}{\infty} \right) = -\frac{3}{100}$  (iii)

$\Rightarrow \frac{1}{F} = -\frac{3}{100} + \frac{1}{20} - \frac{3}{100} \Rightarrow F = -100 \text{ cm}$

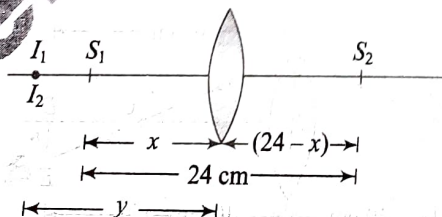
6. (a) The given condition will be satisfied only if one source ( $S_1$ ) placed on one side such that  $u < f$  (i.e., it lies under the focus). The other source ( $S_2$ ) is placed on the other side of the lens such that  $u > f$  (i.e., it lies beyond the focus).

If  $S_1$  is the object for lens, then  $\frac{1}{f} = \frac{1}{-y} - \frac{1}{-x}$

$\Rightarrow \frac{1}{y} = \frac{1}{x} - \frac{1}{f}$  (i)

If  $S_2$  is the object for lens, then

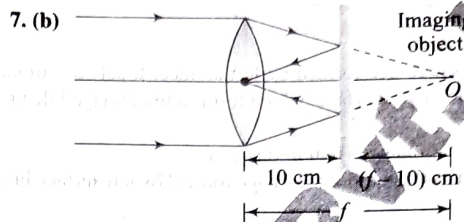
$\frac{1}{f} = \frac{1}{+y} - \frac{1}{-(24-x)} \Rightarrow \frac{1}{y} = \frac{1}{f} - \frac{1}{(24-x)}$  (ii)



From equations (i) and (ii)

$\frac{1}{x} - \frac{1}{f} = \frac{1}{f} - \frac{1}{(24-x)} \Rightarrow \frac{1}{x} + \frac{1}{(24-x)} = \frac{2}{f}$

$\Rightarrow x^2 - 24x + 108 = 0$ . After solving the equation,  $x = 18 \text{ cm}$ ,  $6 \text{ cm}$ .



From the figure, using property of plane mirror  
 Image distance = Object distance  
 $f - 10 = 10 \Rightarrow f = 20 \text{ cm}$

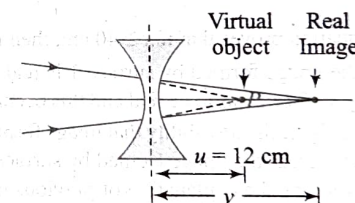
8. (d) Apparent distance of fish from lens  $u = 0.2 + \frac{h}{\mu}$   
 $= 0.2 + \frac{0.4}{4/3} = 0.5 \text{ m}$

From  $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{(+3)} = \frac{1}{v} - \frac{1}{(-0.5)} \Rightarrow v = -0.6 \text{ m}$

The image of the fish is still where the fish is 0.4 m below the water surface.

9. (d) By using lens formula

$\frac{1}{-16} = \frac{1}{v} - \frac{1}{(+12)} \Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{16} = \frac{4-3}{48} \Rightarrow v = 48 \text{ cm}$



## Multiple Correct Answers Type

10. (a, d)

For a lens  $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{v} = \frac{1}{u} + \frac{1}{f}$  (i)

Also  $m = \frac{f-v}{f} = 1 - \frac{v}{f} \Rightarrow m = \left( -\frac{1}{f} \right) v + 1$  (ii)

On comparing equations (i) and (ii) with  $y = mx + c$

It is clear that relationship between  $\frac{1}{v}$  vs.  $\frac{1}{u}$  and  $m$  vs.  $v$  is linear.

11. (a, c)

For the refraction at I surface

$\frac{\mu_2}{v_1} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1}$  (i)

For the reflection at II surface

$\frac{1}{v_2} + \frac{1}{v_1} = \frac{2}{R_2}$  (ii)

Again refraction at the first surface

$$\frac{\mu_1}{-v} - \frac{\mu_2}{-v_2} = \frac{\mu_1 - \mu_2}{-R_1} \quad \text{(iii)}$$

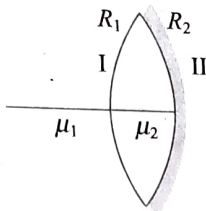
From equations (i), (ii) and (iii)

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{2\left(\frac{\mu_2}{\mu_1}\right)}{R_2} - \frac{2\left(\frac{\mu_2}{\mu_1} - 1\right)}{R_1}$$

$$R_1 = 20 \text{ cm}, R_2 = -20 \text{ cm}, \mu_2 = \frac{3}{2}, \mu_1 = \frac{5}{3}$$

$$\begin{aligned} \frac{1}{f} &= \frac{2\left(\frac{3/2}{5/3}\right)}{-20} - \frac{2\left(\frac{3/2}{5/3} - 1\right)}{20} \\ &= \frac{-9}{5 \times 20} + \frac{2}{20 \times 10} = \frac{-8}{100} \end{aligned}$$

$\therefore f = -12.5 \text{ cm}$  (It acts as converging mirror)



So,  $OB'_1 = 0.3 \text{ m}$

and  $OA_1 = 3.0 \text{ m}$ , So  $OA'_1 = 1.5 \text{ m}$

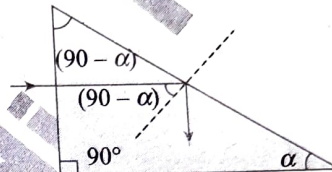
So,  $B'$  will move  $0.3 \text{ m}$  below the optic axis of lens. Similarly  $A'$  will move  $0.6 + 1.5 = 2.1 \text{ m}$  below the optic axis of lens.

15. (d) As in the last problem

## DPP 1.5

### Single Correct Answer Type

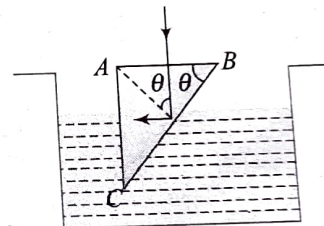
1. (d) If  $\alpha$  = maximum value of base angle for which light is totally reflected from hypotenuse.



$(90^\circ - \alpha) = C$  = minimum value of angle of incidence at hypotenuse for total internal reflection

$$\sin(90^\circ - \alpha) = \sin C = \frac{1}{\mu} \Rightarrow \cos \alpha = \frac{1}{\mu} \Rightarrow \alpha = \cos^{-1}\left(\frac{1}{\mu}\right)$$

2. (b) For total internal reflection from surface BC



$$\theta \geq C \Rightarrow \sin \theta \geq \sin C$$

$$\Rightarrow \sin \theta \geq \left(\frac{1}{\mu_g}\right)$$

$$\Rightarrow \sin \theta \geq \left(\frac{\mu_{\text{Liquid}}}{\mu_{\text{Prism}}}\right)$$

$$\sin \theta \geq \left(\frac{1.32}{1.56}\right) \Rightarrow \sin \theta \geq \frac{11}{13}$$

$$3. (c) \delta_{\text{Prism}} = (\mu - 1)A = (1.5 - 1)4^\circ = 2^\circ$$

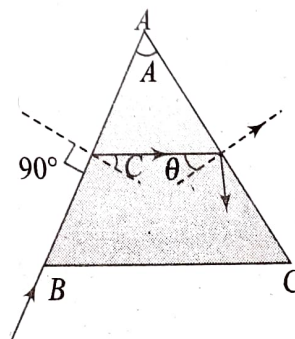
$$\therefore \delta_{\text{Total}} = \delta_{\text{Prism}} + \delta_{\text{Mirror}}$$

$$= (\mu - 1) + (180 - 2i) = 2^\circ + (180 - 2 \times 2) = 176^\circ$$

4. (c) From ray diagram

$$A = C + \theta \text{ for TIR at AC}$$

$$\theta > C \text{ so } A > 2C$$



### Comprehension Type

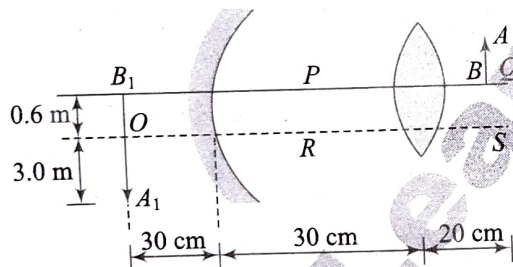
12. (b)  $u = -20 \text{ cm}$   $f = 15 \text{ cm}$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \text{ gives } v = 60 \text{ cm}$$

$$m_1 = \frac{v}{u} = \frac{60}{-20} = -3$$

13. (c)  $A_1B_1$  is the image formed by lens.

It will behave like a virtual object for mirror at a distance of  $30 \text{ cm}$  from it.



$$u = +3 \text{ cm}, f = -30 \text{ cm}$$

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \text{ gives } v = -15 \text{ cm}$$

$$\text{Linear magnification, } m_2 = -\frac{v}{u} = -\frac{(-15)}{30} = +\frac{1}{2}$$

14. (a) Total magnification of image,

$$m = m_1 \times m_2 = \frac{3}{2}$$

$$A'B' = m(AB)$$

$$= \frac{3}{2} \times 1.2 = 1.8 \text{ cm}$$

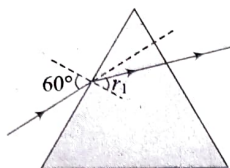
First image is formed by lens. So, the first image will be  $-3 \times 1.2 = -3.6 \text{ cm}$ , i.e.,  $3.6 \text{ cm}$  in length below of optic axis of lens, as shown in the solution of last problem. Now second image is

formed by mirror for which linear magnification is  $+\frac{1}{2}$ . The

image will reduce to half about optic axis of mirror. In the last problem  $OB_1 = 0.6 \text{ m}$ ,

# S.10 Optics and Modern Physics

5. (d) From figure it is clear that  $\angle e = \angle r_2 = 0$



$$\text{From } A = r_1 + r_2$$

$$\Rightarrow r_1 = A = 45^\circ$$

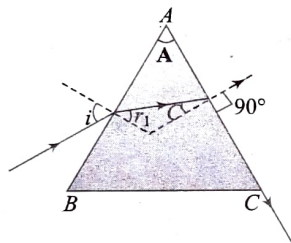
$$\therefore \mu = \frac{\sin i}{\sin r_1} = \frac{\sin 60}{\sin 45} = \sqrt{\frac{3}{2}}$$

$$\text{Also from } l + e = A + \delta \Rightarrow 60 + 0 = 45 + \delta \Rightarrow \delta = 15^\circ$$

6. (c) By formula  $\delta = (n-1)A \Rightarrow 34 = (n-1)A$  and in the second position  $\delta' = (n-1)\frac{A}{2}$

$$\therefore \frac{34}{\delta'} = \frac{(n-1)A}{(n-1)\frac{A}{2}} \text{ or } \delta' = \frac{34}{2} = 17^\circ$$

7. (b) From figure



$$A = r_1 + r_2 = r_1 + \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\Rightarrow r_1 = 75 - \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\Rightarrow 75 - 45 = 30^\circ$$

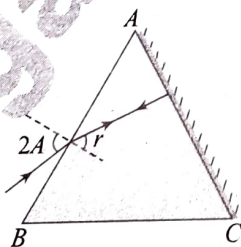
From Snell's law At B

$$m = \frac{\sin i}{\sin r_1} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin 30^\circ} \Rightarrow i = 45^\circ$$

8. (c) In both A and B, the refracted ray is parallel to the base of prism.

9. (a) According to given conditions TIR must take place at both the surfaces AB and AC. Hence only option (a) is correct.

10. (b)  $A = r + 0$  and  $\mu = \frac{\sin i}{\sin r}$



$$\Rightarrow \mu = \frac{\sin 2A}{\sin A} = \frac{2 \sin A \cos A}{\sin A} = 2 \cos A$$

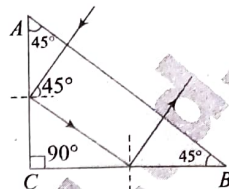
11. (a) From the figure it is clear that TIR takes place at surface AC and BC

$$\text{i.e., } 45^\circ > C$$

$$\Rightarrow \sin 45^\circ > \sin C$$

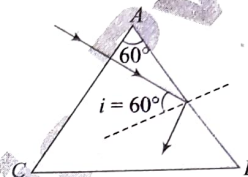
$$\Rightarrow \frac{1}{\sqrt{2}} > \frac{1}{\mu} \Rightarrow \mu > \sqrt{2}$$

$$\text{Hence } \mu_{\text{least}} = \sqrt{2}$$



12. (d) Critical angle for the material of prism  $C = \sin^{-1}\left(\frac{1}{\mu}\right) = \sin^{-1}$

$= 42^\circ$  since angle of incidence at surface AB ( $60^\circ$ ) is greater than the critical angle ( $42^\circ$ ), hence total internal reflection takes place.



## Comprehension Type

13. (a) 14. (a) 15. (a)

Sol. Let  $r$  be the angle of refraction at Q.

$$\mu = \frac{\sin \theta_1}{\sin r}, \sin \theta_1 = \frac{\mu}{2} \Rightarrow \sin r = \frac{1}{2}, r = 30^\circ$$

Considering ABC as a triangular prism

$$r + r' = A$$

$$30^\circ + r' = 75^\circ \Rightarrow r' = 45^\circ$$

Thus the ray is incident on BC at  $45^\circ$ . It is reflected at the same angle on to AD. From the figure  $\angle RSD$

$$= 360^\circ - (45^\circ + 135^\circ + 60^\circ) = 120^\circ \text{ (consider the quadrilateral)}$$

$$\therefore \text{Angle of incidence at AD} = 120 - 90^\circ = 30^\circ$$

$$\theta_1 = \theta_2$$

$$\text{Total deviation of the ray} = (\theta_1 - 30^\circ) + (180^\circ - 90^\circ) - (\theta_2 - 30^\circ) = 90^\circ \text{ (last one subtracted because it is the opposite)}$$

The deviation being  $90^\circ$ , the incident ray and emergent ray are at right angles.

## DPP 1.6

### Single Correct Answer Type

1. (b) Since  $m = \frac{f_o}{f_e}$

$$\text{Also } m = \frac{\text{Angle subtended by the image}}{\text{Angle subtended by the object}}$$

$$\therefore \frac{f_o}{f_e} = \frac{\alpha}{\beta} \Rightarrow \alpha = \frac{f_o \times \beta}{f_e} = \frac{60 \times 2}{5} = 24^\circ$$

2. (a) When the final image is at the least distance of distinct vision, then

$$m = -\frac{f_o}{f_e} \left(1 + \frac{f_e}{D}\right) = \frac{200}{5} \left(1 + \frac{5}{25}\right) = \frac{200 \times 6}{5 \times 5} = -48$$

When the final image is at infinity, then

$$m = \frac{-f_o}{f_e} = \frac{200}{5} = -40$$

3. (a) For objective lens  $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$$\Rightarrow \frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o} = \frac{1}{4} + \frac{1}{-5} = \frac{1}{20} \Rightarrow v_o = 20 \text{ cm}$$

Now  $M = \frac{v_o}{u_o} \left( 1 + \frac{D}{f_e} \right) = \frac{20}{5} \left( 1 + \frac{20}{10} \right) = 12$

4. (a)  $L_\infty = v_o + f_e \Rightarrow 14 = v_o + 5 \Rightarrow v_o = 9 \text{ cm}$

Magnifying power of microscope for relaxed eye

$$m = \frac{v_o}{u_o} \cdot \frac{D}{f_e} \text{ or } 25 = \frac{9}{u_o} \cdot \frac{25}{5} \text{ or } u_o = \frac{9}{5} = 1.8 \text{ cm}$$

5. (b)  $m_\infty = -\frac{v_o}{u_o} \times \frac{D}{f_e}$

From  $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$$\Rightarrow \frac{1}{(+1.2)} = \frac{1}{v_o} - \frac{1}{(-1.25)} \Rightarrow v_o = 30 \text{ cm}$$

$$\therefore |m_\infty| = \frac{30}{1.25} \times \frac{25}{3} = 200$$

6. (b) For objective lens  $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$$\Rightarrow \frac{1}{(+4)} = \frac{1}{v_o} - \frac{1}{(-4.5)} \Rightarrow v_o = 36 \text{ cm}$$

$$\therefore |m_D| = \frac{v_o}{u_o} \left( 1 + \frac{D}{f_e} \right) = \frac{36}{4.5} \left( 1 + \frac{24}{8} \right) = 32$$

7. (a) Here we treat the line on the objective as the object and the eyepiece as the lens.

Hence  $u = -(f_o + f_e)$  and  $f = f_e$

Now  $\frac{1}{v} - \frac{1}{-(f_o + f_e)} = \frac{1}{f_e}$

Solving we get  $v = \frac{(f_o + f_e)f_e}{f_o}$

Magnification =  $\left| \frac{v}{u} \right| = \frac{f_e}{f_o} = \frac{\text{Image size}}{\text{Object size}} = \frac{l}{L}$

$\therefore$  Magnification of telescope in normal adjustment =  $\frac{f_o}{f_e} = \frac{L}{l}$

8. (a)  $m = \frac{f_o}{f_e} = \frac{30}{2.5} = 12$

Resolving limit =  $\frac{1.22 \lambda}{a} = \frac{1.22 \times (5000 \times 10^{-10})}{0.1}$   
 $= 6.1 \times 10^{-6} \text{ rad}$

9. (b)  $|m| = \frac{f_o}{f_e} = \frac{400}{10} = 40$

Angle subtended by moon on the objective of telescope

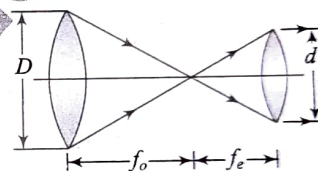
$$\alpha = \frac{3.5 \times 10^3}{3.8 \times 10^3} = \frac{3.5}{3.8} \times 10^{-2} \text{ rad}$$

Also  $|m| = \frac{\beta}{\alpha} \Rightarrow$  Angular size of final image

$$\beta = |m| \times \alpha = 40 \times \frac{3.5}{3.8} \times 10^{-2} = 0.36 \text{ rad}$$

$$= 0.3 \times \frac{180}{\pi} \approx 21^\circ$$

10. (a) Full use of resolving power means whole aperture of objective is use. And for relaxed vision.



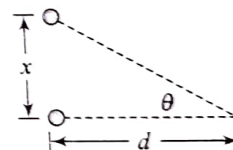
$$\frac{f_o}{f_e} = \frac{D}{d} \Rightarrow \frac{300}{f_e} = \frac{15}{0.3} \Rightarrow f_e = 6 \text{ cm}$$

11. (c)  $\theta = \frac{x}{d} = \frac{1.22 \lambda}{a}$

$$\Rightarrow x = \frac{1.22 \times d}{a}$$

$$= \frac{1.22 \times 5000 \times 10^{-10} \times 10^3}{10 \times 10^{-2}} = 6.1 \text{ mm}$$

i.e., order will be 5 mm



12. (b) By using  $m_\infty = \frac{(L_\infty - f_o - f_e)D}{f_o f_e}$

$$= \frac{(16 - 0.4 - 2.5) \times 25}{0.4 \times 2.5} = 327.5$$

# CHAPTER 2

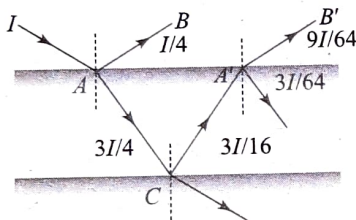
## DPP 2.1

### Single Correct Answer Type

$$1. (c) \frac{I_{\max}}{I_{\min}} = \left( \frac{\sqrt{\frac{I_1}{I_2}} + 1}{\sqrt{\frac{I_1}{I_2}} - 1} \right)^2 = \left( \frac{\sqrt{\frac{9}{1}} + 1}{\sqrt{\frac{9}{1}} - 1} \right)^2 = \frac{4}{1}$$

2. (d) Since the sources are independent, interference will not occur unless they are coherent (such as laser beams, etc.). Hence data is insufficient to predict.

$$3. (d) \text{ From figure } I_1 = \frac{I}{4} \text{ and } I_2 = \frac{9I}{64} \Rightarrow \frac{I_2}{I_1} = \frac{9}{16}$$



$$\text{By using } \frac{I_{\max}}{I_{\min}} = \left( \frac{\sqrt{\frac{I_2}{I_1}} + 1}{\sqrt{\frac{I_2}{I_1}} - 1} \right)^2 = \left( \frac{\sqrt{\frac{9}{16}} + 1}{\sqrt{\frac{9}{16}} - 1} \right)^2 = \frac{49}{1}$$

4. (b)  $\because PR = d \Rightarrow PO = d \sec \theta$  and  $CO = PO \cos 2\theta = d \sec \theta \cos 2\theta$  is

Path difference between the two rays

$$\Delta = CO + PO = (d \sec \theta + d \sec \theta \cos 2\theta)$$

Phase difference between the two rays is

$\phi = \pi$  (One is reflected, while another is direct)

Therefore condition for

constructive interference should be  $\Delta = \frac{\lambda}{2}, \frac{3\lambda}{2}, \dots$

$$\text{or } d \sec \theta (1 + \cos 2\theta) = \frac{\lambda}{2}$$

$$\text{or } \frac{d}{\cos \theta} (2 \cos^2 \theta) = \frac{\lambda}{2} \Rightarrow \cos \theta = \frac{\lambda}{4d}$$

5. (d) Since P is ahead of Q by  $90^\circ$  and path difference between P and Q is  $\lambda/4$ . Therefore at A, phase difference is zero, so intensity is  $4I$ . At C it is zero and at B, the phase difference is  $90^\circ$ , so intensity is  $2I$ .

$$6. (b) \text{ For maxima } 2\pi n = \frac{2\pi}{\lambda} (XO) - 2\pi l$$

$$\text{or } \frac{2\pi}{\lambda} (XO) = 2\pi(n+l) \text{ or } (XO) = \lambda(n+l)$$

7. (a) At any point along the path 1, path difference between the waves is 0.

Hence maxima is obtained all along the path 1.

At any point along the path 2, path difference is  $1.5\lambda$  which is odd multiple of  $\frac{\lambda}{2}$ , so minima is obtained all along the path 2.

8. (b) Here path difference at a point P on the circle is given by

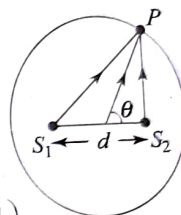
$$\Delta x = d \cos \theta \quad (i)$$

For maxima at P

$$\Delta x = n\lambda \quad (ii)$$

From equations (i) and (ii)

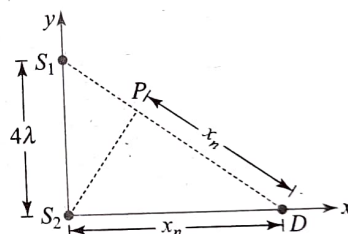
$$n\lambda = d \cos \theta \Rightarrow \theta = \cos^{-1} \left( \frac{n\lambda}{d} \right) = \cos^{-1} \left( \frac{4\lambda}{d} \right)$$



9. (b) From  $\Delta S_1 S_2 D$ ,

$$(S_1 D)^2 = (S_1 S_2)^2 + (S_2 D)^2$$

$$(S_1 P + PD)^2 = (S_1 S_2)^2 + (S_2 D)^2$$



Here  $S_1 P$  is the path difference  $= n\lambda$  for maximum intensity.

$$\therefore (n\lambda + x_n)^2 + (4\lambda)^2 = (x_n)^2$$

$$\text{or } x_n = \frac{16\lambda^2 - n^2\lambda^2}{2n\lambda}$$

$$\text{Then } x_1 = \frac{16\lambda^2 - \lambda^2}{2\lambda} = 7.5\lambda$$

$$x_2 = \frac{16\lambda^2 - 4\lambda^2}{4\lambda} = 3\lambda$$

$$x_3 = \frac{16\lambda^2 - 9\lambda^2}{6\lambda} = \frac{7}{6}\lambda$$

$$x_4 = 0$$

$\therefore$  Number of points for maxima becomes 3.

10. (b) The amplitudes of the waves are

$a_1 = 10 \mu\text{m}$ ,  $a_2 = 4 \mu\text{m}$  and  $a_3 = 7 \mu\text{m}$  and the phase difference

between 1<sup>st</sup> and 2<sup>nd</sup> waves is  $\frac{\pi}{2}$  and that between 2<sup>nd</sup> and 3<sup>rd</sup> waves is  $\frac{\pi}{2}$ . Therefore, phase difference between 1<sup>st</sup> and 3<sup>rd</sup>

is  $\pi$ . Combining 1<sup>st</sup> with 3<sup>rd</sup>, their resultant amplitude is given by

$$A_1^2 = a_1^2 + a_3^2 + 2a_1a_3 \cos \phi$$

$$\text{or } A_1 = \sqrt{10^2 + 7^2 + 2 \times 10 \times 7 \cos \pi}$$

$$= \sqrt{100 + 49 - 140}$$

$$= \sqrt{9} = 3 \mu\text{m in the direction of first.}$$

Now combining this with 2<sup>nd</sup> wave we have the resultant amplitude

$$A^2 = A_1^2 + a_2^2 + 2A_1a_2 \cos \frac{\pi}{2}$$

$$\text{or } A = \sqrt{3^2 + 4^2 + 2 \times 3 \times 4 \cos 90^\circ} = \sqrt{9 + 16} = 5 \mu\text{m}$$

11. (b) The intensity at a point on screen is given by

$$I = 4I_0 \cos^2(\phi/2)$$

where  $\phi$  is the phase difference. In this problem  $\phi$  arises (i) due to initial phase difference of  $\pi/4$  and (ii) due to path difference for the observation point situated at  $\theta = 30^\circ$ . Thus

$$\phi = \frac{\pi}{4} + \frac{2\pi}{\lambda}(d \sin \theta) = \frac{\pi}{4} + \frac{2\pi}{\lambda} \cdot \frac{\lambda}{4}(\sin 30^\circ) = \frac{\pi}{4} + \frac{\pi}{4} = \frac{\pi}{2}$$

$$\text{Thus } \frac{\phi}{2} = \frac{\pi}{4} \text{ and } I = 4I_0 \cos^2(\pi/4) = 2I_0$$

### Matching Column Type

12. (A)  $\rightarrow$  S; (B)  $\rightarrow$  R; (C)  $\rightarrow$  P; (D)  $\rightarrow$  S

The rays are along normal to wavefronts.

### Comprehension Type

13. (a) In both media, wavefronts are parallel light, which is perpendicular to wavefront, thus travels in each medium as a parallel beam.

14. (c) All points are at the same phase on wavefront.

$$\phi_d = \phi_c \text{ and } \phi_f = \phi_e$$

$$(\phi_d - \phi_f) = (\phi_c - \phi_e)$$

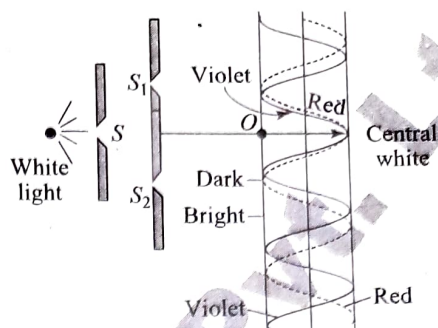
15. (b) Wavefront bends away from normal after refraction in medium 2. Ray of light is perpendicular to wavefront. Thus, ray of light bends towards the normal in medium 2 during refraction. Medium 2 is denser. Speed of light is more in medium 1.

## DPP 2.2

### Single Correct Answer Type

1. (a) In conventional light source, light comes from a large number of independent atoms, each atom emitting light for about  $10^{-9}$  sec, i.e., light emitted by an atom is essentially a pulse lasting for only  $10^{-9}$  sec. Light coming out from two slits will have a fixed phase relationship only for  $10^{-9}$  sec. Hence any interference pattern formed on the screen would last only for  $10^{-9}$  sec, and then the pattern will change. The human eye can notice intensity changes, which last at least for a tenth of a second and hence we will not be able to see any interference pattern. Instead due to rapid changes in the pattern, we will only observe a uniform intensity over the screen.

2. (c) In young's double slit experiment, if white light is used in place of monochromatic light, then the central fringe is white and some coloured fringes around the central fringe are formed.



Since  $\beta_{\text{red}} > \beta_{\text{violet}}$ , the bright fringe of violet colour forms first and that of the red forms later.

It may be noted that the inner edge of the dark fringe is red, while the outer edge is violet. Similarly, the inner edge of the bright fringe is violet and the outer edge is red.

3. (c) If path difference  $\Delta = (SS_1 + S_1O) - (SS_2 + S_2O) = n\lambda$ ,  $n = 0, 1, 2, 3, \dots$  the central fringe at O is a bright fringe and if the path difference  $\Delta = \left(n - \frac{1}{2}\right)\lambda$ ,  $n = 1, 2, 3, \dots$  the central bright fringe will be a dark fringe.

4. (c) Suppose slit widths are equal, so they produce waves of equal intensity say  $I'$ . Resultant intensity at any point  $I_R = 4I' \cos^2 \phi$  where  $\phi$  is the phase difference between the waves at the point of observation.

$$\text{For maximum intensity } \phi = 0^\circ \Rightarrow I_{\text{max}} = 4I' = I \quad (\text{i})$$

If one of slit is closed, resultant intensity at the same point will be  $I'$  only, i.e.,  $I' = I_0$  (ii)

Comparing equations (i) and (ii), we get

$$I = 4I_0$$

5. (c) Slit width ratio = 1 : 9

Since slit width ratio is the ratio of intensity and intensity  $\propto$  (amplitude)<sup>2</sup>

$$\therefore I_1 : I_2 = 1 : 9$$

$$\Rightarrow a_1^2 : a_2^2 = 1 : 9 \Rightarrow a_1 : a_2 = 1 : 3$$

$$I_{\text{max}} = (a_1 + a_2)^2, I_{\text{min}} = (a_1 - a_2)^2 \Rightarrow \frac{I_{\text{min}}}{I_{\text{max}}} = \frac{1}{4}$$

6. (b) By using phase difference  $\phi = \frac{2\pi}{\lambda}(\Delta)$

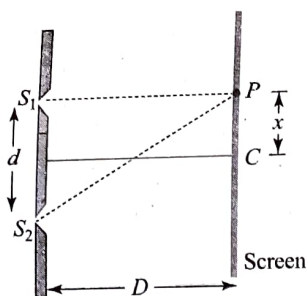
For path difference  $\lambda$ , phase difference  $\phi_1 = 2\pi$  and for path difference  $\lambda/4$ , phase difference  $\phi_2 = \pi/2$ .

$$\text{Also by using } I = 4I_0 \cos^2 \frac{\phi}{2} \Rightarrow \frac{I_1}{I_2} = \frac{\cos^2(\phi_1/2)}{\cos^2(\phi_2/2)}$$

$$\Rightarrow \frac{K}{I_2} = \frac{\cos^2(2\pi/2)}{\cos^2(\pi/2)} = \frac{1}{1/2} \Rightarrow I_2 = \frac{K}{2}$$

7. (a) Suppose P is a point in front of one slit at which intensity is to be calculated from figure it is clear that  $x = \frac{d}{2}$ . Path difference between the waves reaching at P

$$\Delta = \frac{xd}{D} = \frac{\left(\frac{d}{2}\right)d}{10d} = \frac{d}{20} = \frac{5\lambda}{20} = \frac{\lambda}{4}$$



Hence corresponding phase difference

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$$

Resultant intensity at P

$$I = I_{\max} \cos^2 \frac{\phi}{2} = I_0 \cos^2 \left( \frac{\pi}{4} \right) = \frac{I_0}{2}$$

8. (d) Intensity of each source  $= I_0 = \frac{100}{4} = 25$  unit

If the intensity of one of the source is reduced by 36%, then  $I_1 = 25$  unit and

$$I_2 = 25 - 25 \times \frac{36}{100} = 16 \text{ (unit)}$$

Hence resultant intensity at the same point will be

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} = 25 + 16 + 2\sqrt{25 \times 16} = 81 \text{ unit}$$

9. (c) Path difference at point P  $= \frac{xd}{D}$

$$\text{Phase difference at point P} = \frac{2\pi}{\lambda} \frac{xd}{D} = \frac{2\pi x}{\beta}$$

$I_0 = 4I_1$ , intensity at point P

$$I = I_1 + I_1 + 2I_1 \cos \frac{2\pi x}{\beta} = 2I_1 \left[ 1 + \cos \frac{2\pi x}{\beta} \right]$$

$$= I_0 \cos^2 \frac{\pi x}{\beta}$$

10. (b) By using  $I = 4I_0 \cos^2 \left( \frac{\phi}{2} \right) = 4I_0 \cos^2 \left( \frac{\pi \Delta}{\lambda} \right)$

$$\left\{ \because \phi = \frac{2\pi}{\lambda} \Delta \right\}$$

$$\Rightarrow \frac{I_1}{I_2} = \frac{\cos^2 \left( \frac{\pi \Delta_1}{\lambda} \right) \cos^2 \left( \frac{\pi \cdot \frac{\lambda}{4}}{\lambda} \right)}{\cos^2 \left( \frac{\pi \Delta_2}{\lambda} \right) \cos^2 (0)} = \frac{1}{2}$$

11. (c)  $n_1 \lambda_1 = n_2 \lambda_2 \Rightarrow 60 \times 4000 = n_2 \times 6000 \Rightarrow n_2 = 40$

12. (c) For brightness, path difference  $= n\lambda = 2\lambda$   
So second is bright.

13. (a)  $\beta = \frac{\lambda D}{d} \Rightarrow \beta \propto D$

$$\Rightarrow \frac{\beta_1}{\beta_2} = \frac{D_1}{D_2} \Rightarrow \frac{\beta_1 - \beta_2}{\beta_2} = \frac{D_1 - D_2}{D_2} \Rightarrow \frac{\Delta \beta}{\Delta D} = \frac{\beta_2}{D_2} = \frac{\lambda_2}{d_2}$$

$$= \lambda_2 = \frac{3 \times 10^{-5}}{5 \times 10^{-2}} \times 10^{-3} = 6 \times 10^{-7} \text{ m} = 6000 \text{ \AA}$$

14. (b) For maximum intensity on the screen

$$d \sin \theta = n\lambda \Rightarrow \sin \theta = \frac{n\lambda}{d} = \frac{n(2000)}{7000} = \frac{n}{3.5}$$

Since maximum value of  $\theta$  is 1

So  $n = 0, 1, 2, 3$ , only. Thus only seven maximas can be obtained on both sides of the screen.

### Multiple Correct Answers Type

15. (a, b)

(a) the maximum path difference will be less than  $\lambda$  for  $d = \lambda$ . Thus, only one maximum will be observed.

(b) For  $\lambda < d < 2\lambda$ , maximum path difference will be less than  $2\lambda$ . Thus, 3 maximas will be observed.

(c) Initially  $I_1 = 4I_0$  and  $I_2 = I_0$

$$\text{So, } I_{\max} = 9I_0; I_{\min} = I_0$$

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos(\Delta\phi)$$

For maximum intensity  $\cos(\Delta\phi) = 1$

Minimum intensity  $\cos(\Delta\phi) = -1$

So,  $I'_1 = I_0$  and  $I'_2 = I_0$  (given)

Thus,  $I'_{\max} = 4I_0$  and  $I'_{\min} = 0$  (decreases)

(d)  $I'_1 = 4I_0$  and  $I'_2 = 4I_0$  (given)

So,  $I'_{\max} = 16I_0$  and  $I'_{\min} = 0$

## DPP 2.3

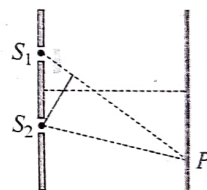
### Single Correct Answer Type

1. (b) Path difference at

$$P \Delta = (S_1 P + (\mu - 1)t) - S_2 P$$

$$= (S_1 P - S_2 P) + (\mu - 1)t$$

2. (d) In the presence of thin glass plate, the fringe pattern shifts, but no change in fringe width.



3. (a) Shift  $= \frac{\beta}{\lambda} (\mu - 1)t = \frac{\beta}{(5000 \times 10^{-10})} (1.5) \times 2 \times 10^{-6} = 2\beta$   
i.e., 2 fringes upwards.

4. (d) If shift is equivalent to  $n$  fringes, then

$$n = \frac{(\mu - 1)t}{\lambda} \Rightarrow n \propto t \Rightarrow \frac{t_2}{t_1} = \frac{n_2}{n_1} \Rightarrow t_2 = \frac{n_2}{n_1} \times t$$

$$t_2 = \frac{20}{30} \times 4.8 = 3.2 \text{ mm}$$

5. (a) The number of fringes shifting is decided by the extra path difference produced by introducing the glass plate. The extra path difference is  $(\mu - 1)t = n\lambda$

$$\text{or } (1.5 - 1) \times 0.1 \times 10^{-3} = n \times 500 \times 10^{-9}$$

$$\Rightarrow n = 100$$

6. (c) Shift  $= \frac{\beta}{\lambda} (\mu - 1)t$

$$\Rightarrow 7\beta = \frac{\beta}{\lambda} (\mu - 1)t \Rightarrow t = \frac{7\lambda}{(\mu - 1)} = \frac{7 \times 600}{(1.5 - 1)} = 8400 \text{ nm}$$

7. (a) Fringe shift is given by  $x = \frac{(\mu - 1)t\beta}{\lambda}$

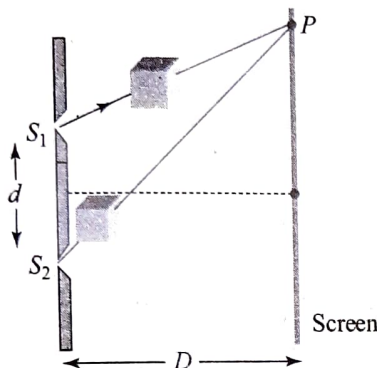
For the first plate,  $x = \frac{(\mu_1 - 1)t\beta}{\lambda}$

For the second plate  $\frac{3}{2}x = \frac{(\mu_2 - 1)t\beta}{\lambda}$

$$\Rightarrow \left( \frac{\mu_2 - 1}{\mu_1 - 1} \right) = \frac{3}{2} \Rightarrow \left( \frac{\mu_2 - 1}{1.5 - 1} \right) = \frac{3}{2}$$

$$\Rightarrow \mu_2 = 1.75$$

8. (a) Shift  $\Delta x = \frac{\beta}{\lambda}(\mu - 1)t$



Shift due to one plate  $\Delta x_1 = \frac{\beta}{\lambda}(\mu_1 - 1)t$

Shift due to another path  $\Delta x_2 = \frac{\beta}{\lambda}(\mu_2 - 1)t$

Net shift  $\Delta x = \Delta x_2 - \Delta x_1 = \frac{\beta}{\lambda}(\mu_2 - \mu_1)t$  (i)

Also it is given that  $\Delta x = 5\beta$  (ii)

Hence  $5\beta = \frac{\beta}{\lambda}(\mu_1 - \mu_2)t$

$$\Rightarrow t = \frac{5\lambda}{(\mu_2 - \mu_1)} = \frac{5 \times 4800 \times 10^{-10}}{(1.7 - 1.4)} = 8 \times 10^{-6} \text{ m} = 8 \mu\text{m}$$

Next, 11th minima of 400 nm will coincide with 8th minima of 560 nm

Location of this minima is

$$= \frac{21(1000)(400 \times 10^{-6})}{2 \times 0.1} = 42 \text{ mm}$$

$\therefore$  Required distance = 28 mm

### Comprehension Type

For Problems 9 to 15

Given  $\lambda = 5000 \text{ \AA}$

Distance of P from O = 1 mm

Path difference at P when screen is in position (1) = 11250  $\text{\AA}$

Distance of Q from O = 2.5 mm

Angular fringe width when screen is in position (2) =  $\frac{1}{90}$  radian

9. (a) Path difference at P = 11250  $\text{\AA}$   
 $= 2.25\lambda$  ( $\lambda = 5000 \text{ \AA}$ )

Phase difference  $\frac{2\pi}{\lambda}$  (path difference)

$$= \frac{2\pi}{\lambda} \times 2.25\lambda = 4.5\pi$$

Phase difference  $\phi$  enters the expression of resultant intensity as

$$\cos \phi = (I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi)$$

$$\cos (4.5\pi) = \cos (4\pi + 0.5\pi) = \cos (0.5\pi)$$

Hence phase difference is effectively  $0.5\pi = 90^\circ$

10. (c) Let I be the intensity of light emitted by each slit. Resultant intensity can be expressed as

$$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$$

$$= I + I + 2I \cos \phi = 2I(1 + \cos \phi)$$

$$I_R = 4I \cos^2 \frac{\phi}{2}$$

Intensity of a bright fringe, say, the central maximum formed at O is  $I_0$ . At O,  $\phi = 0^\circ$ .

$$I_0 = 4I$$

Hence at any point,  $I_R = I_0 \cos^2 \frac{\phi}{2}$

At P, as obtained in Q. 9.

$$\phi = 4.5\pi \text{ or effectively } 0.5\pi = \pi/2$$

$$I_R = I_0 \cos^2 \frac{\pi}{4} = \frac{I_0}{2}$$

11. (a) Point P is at distance  $y = 1 \text{ mm}$  from O. Therefore, path

difference at P,  $\Delta = \frac{yd}{D} = \frac{10^{-3}d}{D}$

But  $\Delta = 11250 \text{ \AA} = 2.25\lambda$

$$\frac{10^{-3}d}{D} = 2.25\lambda$$

$$\beta = \frac{\lambda D}{d} = \frac{10^{-3}}{2.25} \text{ m} = \frac{4}{9} \text{ mm}$$

$\therefore$  Fringe width  $\beta = \frac{4}{9} \text{ mm}$

12. (c) Point Q is  $y = 2 \text{ mm}$  from O. Hence path difference

$$\Delta = \frac{2.0 \times 10^{-3}d}{D}$$

But  $\frac{10^{-3}d}{D} = 2.25\lambda$

$$\Delta = 2 \times 2.25\lambda \Rightarrow \Delta = 4.5\lambda$$

$$f = \frac{2\pi}{\lambda}(\Delta) = 9\pi$$

$$I_R = I_0 \cos^2 \left( \frac{9\pi}{2} \right) = 0$$

13. (b) Angular fringe width, when screen is at position (2), is  $\frac{1}{90}$  radian. Angular width of a fringe =  $\frac{\lambda}{d}$  and does not depend on D. (Angular fringe width, when screen is at position (1), is also  $\frac{1}{90}$  radian).

$$\frac{\lambda}{d} = \frac{1}{90} \text{ radian}$$

$$d = \frac{\lambda}{1/90} = \frac{5000 \times 10^{-10}}{1/90} \text{ m}$$

$\therefore d = 45 \mu\text{m}$

14. (a) Fringe width, when screen is at position (1),

$$\beta = \frac{4}{9} \text{ mm} \Rightarrow \beta = \frac{\lambda D}{d}$$

$$\frac{4}{9} \times 10^3 = \frac{5000 \times 10^{-10} \times D}{45 \times 10^{-6}}$$

$$D = 20 \text{ cm}$$

The screen, at position (1), is 2.25 cm from the slits. At position (2), since the fringe width is 50% more than the earlier value, hence D increases by 50% [ $\beta \propto D$ , for given  $\lambda$  and  $d$ ].

Hence distance of screen, at position (2), from the slits = 20 + 20/2 = 30 cm

15. (b) Angular position is expressed by  $\theta$ . For fifth bright fringe, path difference =  $d \sin \theta = 5 \lambda$

$$\sin \theta = \frac{5 \lambda}{d} = \frac{5 \times 5000 \times 10^{-10}}{45 \times 10^{-6}} = \frac{1}{8}$$

$$\therefore \theta = \frac{1}{18} \text{ rad}$$

## DPP 2.4

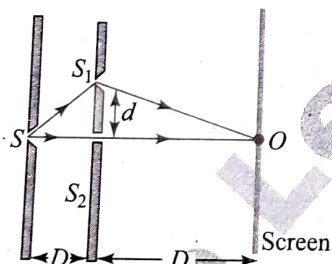
### Single Correct Answer Type

1. (c) Distance of  $n^{\text{th}}$  bright fringe  $y_n = \frac{n \lambda D}{d}$ , i.e.,  $y_n \propto \lambda$

$$\therefore \frac{x_{n_1}}{x_{n_2}} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{x(\text{Blue})}{x(\text{Green})} = \frac{4360}{5460}$$

$$\therefore x(\text{Green}) > x(\text{Blue})$$

2. (c) Path difference between the waves reaching at P,  $\Delta = \Delta_1 + \Delta_2$  where  $\Delta_1$  = Initial path difference



$\Delta_2$  = Path difference between the waves after emerging from slits.

$$\Delta_1 = SS_1 - SS_2 = \sqrt{D^2 + d^2} - D$$

$$\text{and } \Delta_2 = S_1O - S_2O = \sqrt{D^2 + d^2} - D$$

$$\therefore \Delta = 2 \left[ \left( D^2 + d^2 \right)^{\frac{1}{2}} - D \right] = 2 \left[ \left( D^2 + \frac{d^2}{2} \right) - D \right]$$

$$= \frac{d^2}{D} \text{ (from binomial expansion)}$$

For obtaining dark at O,  $\Delta$  must be equal to  $(2n-1) \frac{\lambda}{2}$ , i.e.,

$$\frac{d^2}{D} = (2n-1) \frac{\lambda}{2} \Rightarrow d \sqrt{\frac{(2n-1)\lambda D}{2}}$$

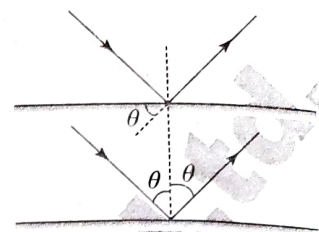
$$\text{For minimum distance } n = 1 \text{ so } d = \sqrt{\frac{\lambda D}{2}}$$

3. (c) Path difference =  $2d \sin \theta$

$\therefore$  For constructive interference

$$2d \sin \theta = n \lambda$$

$$\Rightarrow \theta = \sin^{-1} \left( \frac{n \lambda}{2d} \right)$$



4. (a) The film appears bright when the path difference

$(2\mu t \cos r)$  is equal to odd multiple of  $\frac{\lambda}{2}$

i.e.,  $2\mu t \cos r = (2n-1) \frac{\lambda}{2}$  where  $n = 1, 2, 3 \dots$

$$\therefore \lambda = \frac{4\mu t \cos r}{(2n-1)}$$

$$= \frac{4 \times 1.4 \times 10,000 \times 10^{-10} \times \cos 0}{(2n-1)} = \frac{56000}{(2n-1)} \text{ \AA}$$

$$\therefore \lambda = 56000 \text{ \AA}, 18666 \text{ \AA}, 8000 \text{ \AA}, 6222 \text{ \AA}, 5091 \text{ \AA}, 4308 \text{ \AA}, 3733 \text{ \AA}$$

The wavelength which are not within specified range are to be refracted.

5. (a) If thin film appears dark

$$2\mu t \cos r = n \lambda \text{ for normal incidence } r = 0^\circ$$

$$\Rightarrow 2\mu t = n \lambda \Rightarrow t = \frac{n \lambda}{2\mu}$$

$$\Rightarrow t_{\min} = \frac{\lambda}{2\mu} = \frac{5890 \times 10^{-10}}{2 \times 1} = 2.945 \times 10^{-7} \text{ m}$$

6. (c) With white light, the rays reaching the centre has zero path difference. So we get white fringe at the centre and coloured near the central fringe.

$$7. (b) d = \frac{D \lambda}{\beta} = \frac{1 \times 5 \times 10^{-7}}{5 \times 10^{-3}} = 10^{-4} \text{ m} = 0.1 \text{ mm}$$

$$8. (b) \beta = \frac{(a+b)\lambda}{2a(\mu-1)\alpha}$$

where  $a$  = distance between the source and biprism = 0.3 m

$b$  = distance between the biprism and screen = 0.7 m

$\alpha$  = Angle of prism =  $1^\circ$ ,  $\mu = 1.5$ ,  $\lambda = 6000 \times 10^{-10} \text{ m}$

$$\text{Hence, } \beta = \frac{(0.3+0.7) \times 6 \times 10^{-7}}{2 \times 0.3(1.5-1) \times \left( 1^\circ \times \frac{\pi}{180} \right)}$$

$$= 1.14 \times 10^{-4} \text{ m} = 0.0114 \text{ cm}$$

### Matching Column Type

9. (A)  $\rightarrow$  P; (B)  $\rightarrow$  P; (C)  $\rightarrow$  R; (D)  $\rightarrow$  P  
 $y = b/2$

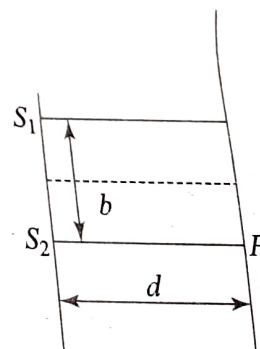
$$\Delta x = S_2P - S_1P = y \frac{b}{d} = \frac{(b/2)b}{d} = \frac{b^2}{2d}$$

For missing wavelengths,

$$\Delta x = \frac{\lambda_1}{2}, \frac{3\lambda_2}{2}, \frac{5\lambda_3}{2}$$

$$\lambda_1 = 2\Delta x = b^2/d$$

$$\lambda_2 = \frac{2\Delta x}{3} = \frac{b^2}{5d} \text{ and } \lambda_3 = \frac{2}{5} \Delta x = \frac{b^2}{5d}$$



At Q,  $\Delta x = \frac{\lambda_1}{2}, \frac{3\lambda_2}{2}$ , etc.

For missing wavelengths,  $\Delta x = \frac{\lambda_1}{2}, \frac{3\lambda_2}{2}$ , etc.

$$\lambda_1 = 2\Delta x \text{ and } \lambda_2 = \frac{2}{3}\Delta x = \frac{2}{3} \frac{yb}{d}$$

$$\frac{2b^2}{3d} \text{ (given)}$$

So,  $y = b$  and  $\lambda_1 = 2\Delta x$

$$2 \frac{yb}{d} = \frac{2b^2}{3d} \text{ (given)}$$

Or  $y = b/3$ , i.e., at  $y = \frac{b}{3}$

This wavelength is missing.

### Comprehension Type

10. (c) Conceptual problem

$$11. (d) \frac{I_{\min}}{I_{\max}} = \frac{[\sqrt{(I_1/I_2)} - 1]^2}{[\sqrt{(I_1/I_2)} + 1]^2}$$

$$= \frac{(x-1)^2}{(x+1)^2} = \frac{1}{16} \quad \text{(given)}$$

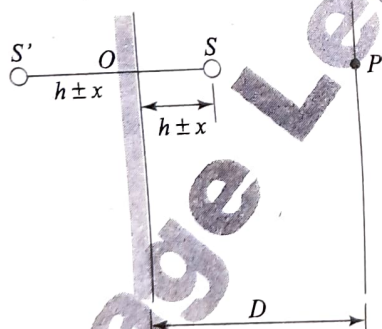
$$\text{Solving } x = \sqrt{\frac{I_1}{I_2}} = \frac{1}{0.6}$$

$$\frac{I_1}{I_2} = \frac{I_0}{0.36I_0} = \frac{1}{0.36}$$

$$\frac{I_1}{I_2} = 0.36 = 36\%$$

12. (b)  $h$  is the path difference initially at  $P$  between the two waves reaching from  $S$  and  $S'$ .

For maximum intensity at  $P$ ,



$$2h = \frac{(2n-1)\lambda}{2}$$

Now if  $OS = h + x$ ,  $OS' = h + x$

Or  $OS = h - x$ ,  $OS' = h - x$

New path difference is either  $(2h + 2x)$  or  $(2h - 2x)$

$$\text{So, } 2(h+x) = \left(n+1 - \frac{1}{2}\right)\lambda$$

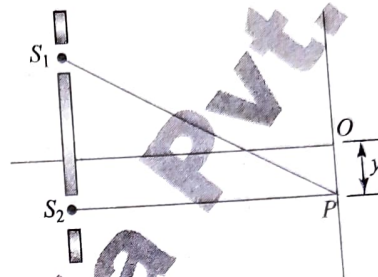
$$\text{and } 2(h-x) = \left(n-1 - \frac{1}{2}\right)\lambda$$

On solving,  $x = \frac{\lambda}{2} = 300 \text{ nm}$

$$13. (b) \Delta x_1 = S_1P - S_2P = \frac{yd}{D}$$

Path difference due to glass sheet

$$\Delta x_2 = \left(\frac{\mu_g}{\mu_m} - 1\right)$$



New path difference is zero, if  $\Delta x_1 = \Delta x_2$

$$y = \left(\frac{\mu_g}{\mu_m} - 1\right) \frac{tD}{d}$$

Putting the values,

$$y = 4.33 \text{ m}$$

14. (b) At point O,

$$\Delta x_1 = 0, \Delta x_2 = \left(\frac{\mu_g}{\mu_m} - 1\right)t$$

Net path difference =  $\Delta x_2$

$$\Delta \phi = \frac{2\pi}{\lambda} (\Delta x_2)$$

Substituting the values,

$$\phi = \frac{2\pi}{6 \times 10^{-7}} \left(\frac{1.5}{4/3} - 1\right) (10.4 \times 10^{-6})$$

$$= \frac{13}{3}\pi$$

$$I(\phi) = I_{\max} \cos^2(\phi/2)$$

$$= I_{\max} \cos^2\left(\frac{13\pi}{6}\right) = 0.75 I_{\max}$$

$$15. (a) \text{ At O, } \Delta x_2 = \Delta x = \left(\frac{\mu_g}{\mu_m} - 1\right)t$$

Maximum intensity at O, for

$$\Delta x = n\lambda \quad (n = 1, 2, 3, \dots)$$

$$\lambda = \frac{\Delta x}{1}, \frac{\Delta x}{2}, \frac{\Delta x}{3}, \dots$$

$$\Delta x = \left[\frac{1.5}{(4/3)} - 1\right] (10.4 \times 10^{-6}) \text{ m} = 1300 \text{ nm}$$

Corresponding,

$$\lambda = 1300 \text{ nm}, \frac{1300}{2} \text{ nm}, \frac{1300}{3} \text{ nm}$$

$$= 1300 \text{ nm}, 650 \text{ nm}, 433 \text{ nm}, \dots$$

One of the wavelengths between 400 and 700 nm is 650 nm

# CHAPTER 3

## DPP 3.1

### Subjective Type

1. Initial de-Broglie wavelength of electron,

$$\lambda_0 = \frac{h}{mv_0}$$

Force on electron in electric field,

$$F = -eE = -e[-E_0\hat{i}] = eE_0\hat{i}$$

$$\text{Acceleration of electron } a = \frac{F}{m} = \frac{eE_0\hat{i}}{m}$$

Velocity of electron after time  $t$ ,

$$\begin{aligned} v &= v_0\hat{i} + \left(\frac{eE_0\hat{i}}{m}\right)t = \left(v_0 + \frac{eE_0}{m}t\right)\hat{i} \\ &= v_0\left(1 + \frac{eE_0}{mv_0}t\right)\hat{i} \end{aligned}$$

de-Broglie wavelength associated with electron at time  $t$  is

$$\lambda = \frac{h}{mv} = \frac{h}{m\left[v_0\left(1 + \frac{eE_0}{mv_0}t\right)\right]} = \frac{\lambda_0}{\left[1 + \frac{eE_0}{mv_0}t\right]}$$

### Single Correct Answer Type

$$2. (c) \quad n = \frac{E\lambda}{hc} = \frac{1 \times 10^{-7} \times 200 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 1 \times 10^{11}$$

$$\text{Number of electrons ejected} = \frac{10^{11}}{10^3} = 10^8$$

$$\therefore V = \frac{q}{4\pi\epsilon_0 r} = \frac{(10^8 \times 1.6 \times 10^{-19}) \times 9 \times 10^9}{4.8 \times 10^{-2}} = 3V$$

3. (c) By using  $I = \frac{P}{A}$  where  $P$  = radiation power

$$\Rightarrow P = I \times A \Rightarrow \frac{nhc}{t\lambda} = IA \Rightarrow \frac{n}{t} = \frac{IA\lambda}{hc}$$

Hence the number of photons entering the eye per sec

$$\left(\frac{n}{t}\right) = \frac{10^{-10} \times 10^{-6} \times 5.6 \times 10^{-7}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 300$$

$$4. (a) \quad E = \frac{12375}{5000} = 2.475 \text{ eV} \approx 4 \times 10^{-19} \text{ J}$$

So the minimum intensity to which the eye can respond

$$I_{\text{Eye}} = (\text{Photon flux}) \times (\text{Energy of a photon})$$

$$\Rightarrow I_{\text{Eye}} = (5 \times 10^4) \times (4 \times 10^{-19}) \approx 2 \times 10^{-14} \text{ (W/m}^2\text{)}$$

Now as lesser the intensity required by a detector for detection, more sensitive it will be

$$\frac{S_{\text{Eye}}}{S_{\text{Ear}}} = \frac{I_{\text{Ear}}}{I_{\text{Eye}}} = \frac{10^{-13}}{2 \times 10^{-14}} = 5, \text{ i.e., as intensity (power) detector,}$$

the eye is five times more sensitive than ear.

5. (d) Radiation force

$$= \frac{2I}{c} \times \text{area} = \frac{I}{c} \cdot \frac{1}{2} \cdot 2R \cdot H = \frac{IRH}{c}$$

6. (b) The radiation pressure

$$P = \frac{F}{A} = \left(\frac{2h}{\lambda}\right) \frac{N}{A} = 2 \frac{I}{c}$$

if reflected completely. It is independent of wavelength. It will depend on the nature of the surface and the intensity of light.

7. (d) De-Broglie wavelength  $\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$

i.e., graph will be a rectangular hyperbola

8. (c)  $\lambda = \frac{h}{mv}$ . Since  $v$  is increasing in case (i), but it is not changing

in case (ii). Hence, in the first case de-Broglie wavelength will change, but in the second case, it remains the same

$$9. (d) \quad \lambda = \frac{h}{\sqrt{2mE}}, \quad \frac{\lambda'}{\lambda} = \sqrt{\frac{E}{E'}} \Rightarrow \frac{E}{E'} = \left(\frac{0.5}{1}\right)^2$$

$$\Rightarrow E' = \frac{E}{0.25} = 4E$$

The energy should be added to decrease wavelength.

$$= E' - E = 3E$$

10. (c) By law of conservation of momentum

$$0 = m_1\vec{v}_1 + m_2\vec{v}_2 \Rightarrow m_1\vec{v}_1 = -m_2\vec{v}_2$$

-ve sign indicates that both the particles are moving in opposite direction. Now de-Broglie wavelengths

$$\lambda_1 = \frac{h}{m_1v_1} \text{ and } \lambda_2 = \frac{h}{m_2v_2} \therefore \frac{\lambda_1}{\lambda_2} = \frac{m_2v_2}{m_1v_1} = 1$$

11. (c) de-Broglie wavelength  $\lambda = \frac{h}{mv_{\text{rms}}}$ , rms velocity of a gas particle

at the given temperature ( $T$ ) is given as

$$\frac{1}{2}mv_{\text{rms}}^2 = \frac{3}{2}kT \Rightarrow v_{\text{rms}} = \sqrt{\frac{3kT}{m}} \Rightarrow mv_{\text{rms}} = \sqrt{3mkT}$$

$$\therefore \lambda = \frac{h}{mv_{\text{rms}}} = \frac{h}{\sqrt{3mkT}}$$

$$\Rightarrow \frac{\lambda_{\text{H}}}{\lambda_{\text{He}}} = \sqrt{\frac{m_{\text{He}}T_{\text{He}}}{m_{\text{H}}T_{\text{H}}}} = \sqrt{\frac{4(273+127)}{2(273+27)}} = \sqrt{\frac{8}{3}}$$

12. (c)  $KE = 2E_0 - E_0 = E_0$  (for  $0 \leq x \leq 1$ )

$$\Rightarrow \lambda_1 = \frac{h}{\sqrt{2mE_0}}$$

$$KE = 2E_0 \text{ (for } x > 1) \Rightarrow \lambda_2 = \frac{h}{\sqrt{4mE_0}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{2}$$

$$13. (c) \lambda = \frac{h}{p} \Rightarrow \lambda - \frac{0.5}{100} \lambda = \frac{h}{p + \Delta p}$$

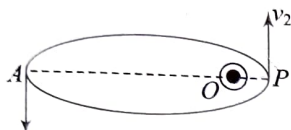
$$\Rightarrow \frac{199\lambda}{200} = \frac{h}{p + \Delta p} = \frac{199}{200} \frac{h}{p}$$

$$\Rightarrow p + \Delta p = \frac{200}{199} p \Rightarrow p = 199 \Delta p$$

### Multiple Correct Answers Type

14. (b, d)

The de-Broglie wavelength of the particle can be varying cyclically between two values  $\lambda_1$  and  $\lambda_2$ , if particle is moving in an elliptical orbit with origin as its one focus. Consider the figure



Let  $v_1$  and  $v_2$  be the speed of particle at A and B respectively and origin is at focus O. If  $\lambda_1$  and  $\lambda_2$  are the de-Broglie wavelengths associated with particle while moving at A and B respectively.

Then,  $\lambda_1 = \frac{h}{mv_1}$  and  $\lambda_2 = \frac{h}{mv_2}$

$$\therefore \frac{\lambda_1}{\lambda_2} = \frac{v_2}{v_1} \text{ since } \lambda_1 > \lambda_2 \quad \therefore v_2 > v_1$$

By the law of conservation of angular momentum, the particle moves faster when it is closer to focus.

From figure, we note that origin O is closer to P than A.

15. (a, c)

de-Broglie wavelength  $\lambda = \frac{h}{mv}$ , where  $mv = p$  (moment)

$$\Rightarrow \lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda}$$

Here,  $h$  is a constant. So,  $p \propto \frac{1}{\lambda} \Rightarrow \frac{p_1}{p_2} = \frac{\lambda_2}{\lambda_1}$

But  $(\lambda_1 = \lambda_2) = \lambda$ , Then,  $\frac{p_1}{p_2} = \frac{\lambda}{\lambda} = 1 \Rightarrow p_1 = p_2$

Thus, their momenta is the same.

$$\text{Also, } E = \frac{1}{2}mv^2 = \frac{1}{2} \frac{mv^2 \times m}{m} = \frac{1}{2} \frac{m^2 v^2}{m} = \frac{1}{2} \frac{p^2}{m}$$

Here,  $p$  is constant  $E \propto \frac{1}{m}$

$$\frac{E_1}{E_2} = \frac{m_2}{m_1} < 1 \Rightarrow E_1 < E_2$$

## DPP 3.2

### Single Correct Answer Type

1. (a) By changing distance of the source, photoelectric current changes. But there is no change in stopping potential.

2. (b) With the increase in intensity of light photoelectric current increases, kinetic energy of ejected electron, stopping potential and work function remain unchanged.  
so A and B will emit photo electrons.

3. (a) The work function has no effect on current so long as  $h\nu > W_0$ . The photoelectric current is proportional to the intensity of light. There is no change in the intensity of light, therefore  $I_1 = I_2$ .

4. (d) According to Einstein's equation

$$h\nu = W_0 + K_{\max} \Rightarrow V_0 = \left(\frac{h}{e}\right)\nu - \frac{W_0}{e}$$

This is the equation of straight line having positive slope  $(h/e)$  and intercept on  $-V_0$  axis equals to  $\frac{W_0}{e}$ .

5. (b)  $I_1 > I_2$  (given)  $\Rightarrow i_1 > i_2$  ( $\because i \propto I$ )

and stopping potential does not depend upon intensity. So its value will be the same ( $V_0$ ).

6. (d) Number of ejected electrons  $\propto (\text{Intensity}) \propto \frac{1}{(\text{Distance})^2}$

Therefore an increment of distance two times will reduce the number of ejected electrons to  $\frac{1}{4}$ th of the previous one.

7. (b) Stopping potential equals to maximum kinetic energy. Since stopping potential is varying linearly with the frequency. Therefore max. KE for both the metals also vary linearly with frequency.

$$8. (c) E = \frac{12375}{4000} = 3.09 \text{ eV}$$

Photoelectrons emit if energy of incident light  $>$  work function.

$$9. (c) E = \frac{hc}{\lambda} - W_0 \text{ and } 2E = \frac{hc}{\lambda'} - W_0$$

$$\Rightarrow \frac{\lambda'}{\lambda} = \frac{E + W_0}{2E + W_0} \Rightarrow \lambda' = \lambda \left( \frac{1 + W_0/E}{2 + W_0/E} \right)$$

$$\text{Since } \frac{(1 + W_0/E)}{(2 + W_0/E)} > \frac{1}{2} \text{ so } \lambda' > \frac{\lambda}{2}$$

$$10. (b) E = W_0 + K_{\max}$$

$$\Rightarrow hf = W_A + K_A$$

$$\text{and } 2hf = W_B + K_B = 2W_A + K_B$$

Dividing equation (i) by (ii)

$$\frac{1}{2} = \frac{W_A + K_A}{2W_A + K_B} \Rightarrow \frac{K_A}{K_B} = \frac{1}{2}$$

$$11. (a) \text{ By using } \frac{hc}{\lambda} = W_0 + \frac{1}{2}mv^2$$

$$\Rightarrow \frac{hc}{400 \times 10^{-9}} = W_0 + \frac{1}{2}mv^2$$

$$\text{and } \frac{hc}{250 \times 10^{-9}} = W_0 + \frac{1}{2}m(2v)^2$$

On solving (i) and (ii)

$$\frac{1}{2}mv^2 = \frac{hc}{3} \left[ \frac{1}{250 \times 10^{-9}} - \frac{1}{400 \times 10^{-9}} \right]$$

From equations (i) and (iii),  $W_0 = 2hc \times 10^6 \text{ J}$

12. (d) From  $E = W_0 + \frac{1}{2}mv_{\max}^2$

$$\Rightarrow 2h\nu_0 = h\nu_0 + \frac{1}{2}mv_1^2 \Rightarrow h\nu_0 = \frac{1}{2}mv_1^2 \quad (i)$$

$$\text{and } 5h\nu_0 = h\nu_0 + \frac{1}{2}mv_2^2 \Rightarrow 4h\nu_0 = \frac{1}{2}mv_2^2 \quad (ii)$$

$$\text{Dividing equation (ii) by (i)} \quad \left(\frac{v_2}{v_1}\right)^2 = \frac{4}{1}$$

$$\Rightarrow v_2 = 2v_1 = 2 \times 4 \times 10^6 = 8 \times 10^6 \text{ m/s}$$

### Comprehension Type

13. (a)  $P = Vi_s$

where  $V$  = accelerating voltage

$i_s$  = saturation photocurrent

$$i_s = \frac{\text{Power of source of light} \times \text{Quantum efficiency} \times \lambda (\text{in } \text{\AA})}{12400}$$

$$= \frac{100 \times .01 \times 124}{12400} = 0.1 \text{ A}$$

$\therefore$  Power = 100 watt

14. (c) Maximum energy of incoming electron

$$= \frac{hc}{\lambda} - \phi + eV$$

$$= \left( \frac{12400}{124} - 10 + 10,000 \right) \text{ eV} = 10,090 \text{ eV}$$

$$\lambda_{\min} = \frac{12400}{10090} = 1.23 \text{ \AA}$$

15. (a) Power provided by accelerating potential = 100 W

Power consumed by the source of

$$124 \text{ \AA} = \frac{100}{(0.5)} = 200 \text{ W}$$

Overall efficiency

$$= \frac{\text{net power of X-ray}}{\text{net power supplied}} = \frac{3 \text{ W}}{100 \text{ W} + 200 \text{ W}} = .01 = 1\%$$

## DPP 3.3

### Single Correct Answer Type

1. (c) The graph between  $V_0$  and  $\nu$  cut the y-axis at  $\nu_0$ .

For the given graphs  $(\nu_0)_{(iv)} > (\nu_0)_{(iii)} > (\nu_0)_{(ii)} > (\nu_0)_{(i)}$

$$\therefore (W_0)_{(iv)} > (W_0)_{(iii)} > (W_0)_{(ii)} > (W_0)_{(i)}$$

2. (b)  $\nu_{\max} = 4 \times 10^8 \text{ cm/sec} = 4 \times 10^6 \text{ m/sec}$

$$\therefore K_{\max} = \frac{1}{2}mv_{\max}^2 = \frac{1}{2} \times 9 \times 10^{-31} \times (4 \times 10^6)^2$$

$$= 7.2 \times 10^{-18} \text{ J} = 45 \text{ eV}$$

$$\text{Hence, stopping potential } |V_0| = \frac{K_{\max}}{e} = \frac{45 \text{ eV}}{e} = 45 \text{ volt}$$

3. (c) Radius of circular path described by a charged particle in a

$$\text{magnetic field is given by } r = \frac{\sqrt{2mk}}{qB}$$

where  $K$  = Kinetic energy of electron

$$\Rightarrow K = \frac{q^2 B^2 r^2}{2m} = \left( \frac{e}{m} \right) \frac{e B^2 r^2}{2}$$

$$= \frac{1}{2} \times 1.7 \times 10^{11} \times 1.6 \times 10^{-19} \times \left( \frac{1}{\sqrt{17}} \times 10^{-5} \right)^2 \times (1)^2$$

$$= 8 \times 10^{-20} \text{ J} = 0.5 \text{ eV}$$

By using  $E = W_0 + K_{\max}$

$$\Rightarrow W_0 = E - K_{\max} = \left( \frac{12375}{2475} \right) \text{ eV} - 0.5 \text{ eV} = 4.5 \text{ eV}$$

4. (c)  $E = W_0 + K_{\max} \Rightarrow \frac{hc}{\lambda_1} = W_0 + E_1$  and  $\frac{hc}{\lambda_2} = W_0 + E_2$

$$\Rightarrow hc = W_0 \lambda_1 + E_1 \lambda_1 \text{ and } hc = W_0 \lambda_2 + E_2 \lambda_2$$

$$\Rightarrow W_0 \lambda_1 + E_1 \lambda_1 = W_0 \lambda_2 + E_2 \lambda_2 \Rightarrow W_0 = \frac{E_1 \lambda_1 - E_2 \lambda_2}{(\lambda_2 - \lambda_1)}$$

5. (d)  $h\nu - W_0 = \frac{1}{2}mv_{\max}^2 \Rightarrow \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{1}{2}mv_{\max}^2$

$$\Rightarrow hc \left( \frac{\lambda_0 - \lambda}{\lambda \lambda_0} \right) = \frac{1}{2}mv_{\max}^2$$

$$\Rightarrow v_{\max} = \sqrt{\frac{2hc}{m} \left( \frac{\lambda_0 - \lambda}{\lambda \lambda_0} \right)}$$

When wavelength is  $\lambda$  and velocity is  $v$ , then

$$v = \sqrt{\frac{2hc}{m} \left( \frac{\lambda_0 - \lambda}{\lambda \lambda_0} \right)} \quad (i)$$

When wavelength is  $\frac{3\lambda}{4}$  and velocity is  $v'$ , then

$$v' = \sqrt{\frac{2hc}{m} \left[ \frac{\lambda_0 - (3\lambda/4)}{(3\lambda/4) \times \lambda_0} \right]} \quad (ii)$$

Divide equation (ii) by (i), we get

$$\frac{v'}{v} = \sqrt{\frac{[\lambda_0 - (3\lambda/4)]}{\frac{3}{4}\lambda\lambda_0} \times \frac{\lambda\lambda_0}{\lambda_0 - \lambda}}$$

$$v' = v \left( \frac{4}{3} \right)^{1/2} \sqrt{\frac{[\lambda_0 - (3\lambda/4)]}{\lambda_0 - \lambda}}, \text{ i.e., } v' > v \left( \frac{4}{3} \right)^{1/2}$$

6. (b) Energy of photons corresponding to light of wave length

$$\lambda_1 = 2475 \text{ \AA} \text{ is } E_1 = \frac{12375}{2475} = 5 \text{ eV}$$

and that corresponding to  $\lambda_2 = 6000 \text{ \AA}$  is

$$E_2 = \frac{12375}{6000} = 2.06 \text{ eV}$$

As  $E_2 < W_0$  and  $E_1 > W_0$

Photoelectric emission is possible with  $\lambda_1$  only. Maximum kinetic energy of emitted photoelectrons  $K = E - W_0 = 5 - 4.8 = 0.2 \text{ eV}$ .

Photoelectrons experience magnetic force and move along a circular path of radius

$$r = \frac{\sqrt{2mk}}{QB} = \frac{\sqrt{2 \times 9 \times 10^{-31} \times 0.2 \times 1.6 \times 10^{-19}}}{1.6 \times 10^{-19} \times 3 \times 10^{-5}}$$

$$= 0.05 \text{ m} = 5 \text{ cm}$$

7. (a) Number of photoelectrons emitted up to  $t = 10$  sec are

$$n = \frac{\text{(Number of photons per unit area per unit time)} \times (\text{Area} \times \text{Time})}{10^6}$$

$$= \frac{1}{10^6} [(10)^{16} \times (5 \times 10^{-4}) \times (10)] = 5 \times 10^7$$

At time  $t = 10$  sec

$$\text{Charge on plate A, } q_A = +ne = 5 \times 10^7 \times 1.6 \times 10^{-19}$$

$$= 8 \times 10^{-12} \text{ C} = 8 \text{ pC}$$

$$\text{and charge on plate B, } q_B = 33.7 - 8 = 25.7 \text{ pC}$$

Electric field between the plates

$$E = \frac{(q_B - q_A)}{2\epsilon_0 A} = \frac{(25.7 - 8) \times 10^{-12}}{2 \times 8.85 \times 10^{-12} \times 5 \times 10^{-4}} = 2 \times 10^3 \frac{\text{N}}{\text{C}}$$

8. (a) As we know in Young's double slit experiment fringe width = separation between two consecutive fringes or dark fringes

$$= \beta = \frac{\lambda D}{d}$$

$$\text{Here } \beta = 2y \Rightarrow 2y = \frac{\lambda D}{d} \Rightarrow \lambda = \frac{2yd}{D}$$

$$\Rightarrow \lambda = \frac{2 \times 1 \times 10^{-3} \times 0.24 \times 10^{-3}}{1.2} = 4 \times 10^{-7} \text{ m} = 4000 \text{ \AA}$$

Energy of light incident on photo plate

$$E(\text{eV}) = \frac{12375}{4000} = 3.1 \text{ eV}$$

According to Einstein photoelectric equation,

$$E = W_0 + eV_0 \Rightarrow V_0 = \frac{(E - W_0)}{e} = \frac{(3 + 2.2)}{e} \text{ eV} \approx 0.9 \text{ V}$$

9. (b) By using  $h\nu - h\nu_0 = K_{\text{max}}$

$$\Rightarrow h(\nu_1 - \nu_0) = K_1 \quad \text{(i)}$$

$$\text{And } h(\nu_2 - \nu_0) = K_2 \quad \text{(ii)}$$

$$\Rightarrow \frac{\nu_1 - \nu_0}{\nu_2 - \nu_0} = \frac{K_1}{K_2} = \frac{1}{K} \text{. Hence } \nu_0 = \frac{K\nu_1 - \nu_2}{K - 1}$$

10. (b)  $E = W_0 + eV_0$

$$\text{For hydrogen atom, } E = +13.6 \text{ eV}$$

$$\therefore +13.6 = 4.2 + eV_0$$

$$\Rightarrow V_0 = \frac{(13.6 - 4.2) \text{ eV}}{e} = 9.4 \text{ V}$$

$$\text{Potential at anode} = -9.4 \text{ V}$$

11. (a) From  $\lambda_0 = \frac{12375}{W_0}$

The maximum wavelength of light required for the photoelectron

$$\text{emission, } (\lambda_0)_{\text{Li}} = \frac{12375}{2.3} = 5380 \text{ \AA}$$

$$\text{Similarly } (\lambda_0)_{\text{Cu}} = \frac{12375}{4} = 3094 \text{ \AA}$$

Since the wavelength 3094 \AA does not fall in the visible region, but it is in the ultraviolet region. Hence to work with visible light, lithium metal will be used for photoelectric cell.

12. (b) Number of photons emitted per second,

$$N = \frac{\eta}{100} \times \frac{P\lambda}{hc}$$

Potential of the sphere after time  $t$  is

$$V' = V - \frac{(Ne)t}{4\pi\epsilon_0 R} = V - \frac{\eta P \lambda e t}{400\pi\epsilon_0 R h c}$$

### Comprehension Type

13. (b)  $\Delta E = \frac{12400}{4.500 \text{ \AA}}$

$$\Delta E = 2.75 \text{ eV}$$

for photoelectric effect

$$\Delta E > W_0 \text{ (work function).}$$

For barium and lithium work function ( $W_0$ ) is less than  $\Delta E$ .

14. (a)  $\Delta E = W_0 + E_k$

$$(E_k) = \Delta E - W_0$$

for maximum value of  $(E_k)$ ,  $W_0$  should be minimum.

$$W_0 \text{ for lithium} = 2.3 \text{ eV}$$

$$(E_k) = \Delta E - W_0 = 2.75 - 2.3 = 0.45 \text{ eV}$$

15. (c) The maximum magnitude of stopping potential will be for metal of least work function.

$\therefore$  Required stopping potential is

$$V_s = \frac{h\nu - \phi_0}{e} = 0.45 \text{ volt}$$

## CHAPTER 4

## DPP 4.1

## Single Correct Answer Type

1. (a)  $A_n = \pi r_n^2 \Rightarrow \frac{A_n}{A_1} = \left(\frac{r_n}{r_1}\right)^2 = \left(\frac{n}{1}\right)^4$  ( $\because r_n \propto n^2$ )

Taking  $\log_e$  both the side,  $\log_e \frac{A_n}{A_1} = 4 \log_e (n)$

Comparing it with  $y = mx + c$ , graph (4) is correct.

2. (b)  $F \propto \frac{v^2}{r}$  also  $v \propto \frac{1}{n}$  and  $r \propto n^2 \Rightarrow F \propto \frac{1}{n^4}$

3. (c) Final energy of electron =  $-13.6 + 12.1 = 1.51$  eV, which corresponds to third level, i.e.,  $n = 3$ . Hence the number of spectral lines emitted =  $\frac{n(n-1)}{2} = \frac{3(3-1)}{2} = 3$

4. (c) Energy of an electron in the ground state of an atom (Bohr's hydrogen like atom) is given as

$$E = -13.6 Z^2 \text{ eV} \quad (Z = \text{atomic number of the atom})$$

$$\Rightarrow E_{\text{ionisation}} = 13.6 Z^2$$

$$\Rightarrow \frac{(E_{\text{ion}})_H}{(E_{\text{ion}})_{Li}} = \left(\frac{Z_H}{Z_{Li}}\right)^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$$

5. (c) By using  $E = -\frac{13.6}{n^2} \text{ eV}$  (for  $H_2$  atom)

$$\Rightarrow -0.544 = -\frac{13.6}{n^2} \Rightarrow n^2 = 25 \Rightarrow n = 5$$

$$\therefore \text{Angular momentum} = n \frac{h}{2\pi} = \frac{5h}{2\pi}$$

6. (b) Acceleration  $a \propto \frac{v^2}{r}$

$$\text{where } v \propto \frac{Z}{n} \text{ and } r \propto \frac{n^2}{Z} \Rightarrow a \propto \frac{Z^3}{n^4}$$

Since both are in the ground state, i.e.,  $n = 1$

$$\text{So } a \propto Z^3 \Rightarrow \frac{a_{\text{He}^+}}{a_{\text{H}}} = \left(\frac{Z_{\text{He}^+}}{Z_{\text{H}}}\right)^3 = \left(\frac{2}{1}\right)^3 = \frac{8}{1}$$

7. (a) Electron after absorbing 10.2 eV energy goes to its first excited state ( $n = 2$ ) from the ground state ( $n = 1$ ).

$$\therefore \text{Increase in momentum} = \frac{h}{2\pi}$$

$$= \frac{6.6 \times 10^{-34}}{6.28} = 1.05 \times 10^{-34} \text{ J-s}$$

8. (c) Speed of electron in  $n^{\text{th}}$  orbit of hydrogen atom  $v = \frac{e^2}{2\epsilon_0 n h}$

$$\text{In ground state } n = 1 \Rightarrow v = \frac{e^2}{2\epsilon_0 h}$$

$$\Rightarrow \frac{v}{c} = \frac{e^2}{2\epsilon_0 c h} = \frac{(1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 3 \times 10^8 \times 6.6 \times 10^{-34}} = \frac{1}{137}$$

9. (c) Excitation potential =  $\frac{\text{Excitation energy}}{e}$

Minimum excitation energy corresponds to excitation from  $n = 1$  to  $n = 2$

$\therefore$  Minimum excitation energy in hydrogen atom =  $-3.4 - (-13.6) = +10.2$  eV

so minimum excitation potential = 10.2 eV.

10. (a) Orbital speed varies inversely as the radius of the orbit. Energy increases with the increase in quantum number.

11. (d)  $mvr_n = \frac{nh}{2\pi} \Rightarrow pr_n = \frac{nh}{2\pi} \Rightarrow \frac{h}{\lambda} \times r_n = \frac{nh}{2\pi}$

$$\Rightarrow \lambda = \frac{2\pi r_n}{n}, \text{ for the first orbit } n = 1 \text{ so } \lambda = 2\pi r_1$$

= circumference of first orbit

12. (a) Here radius of electron orbit  $r \propto 1/m$  and energy  $E \propto m$ , where  $m$  is the mass of the electron.

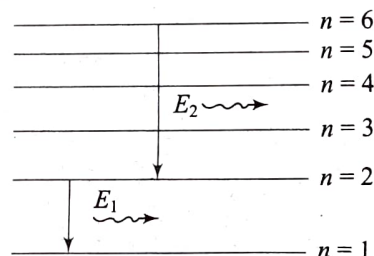
Hence energy of hypothetical atom,

$$E_0 = 2 \times (-13.6 \text{ eV}) = -27.2 \text{ eV and radius } r_0 = \frac{a_0}{2}$$

13. (a)  $\because E_1 > E_2$

$$\therefore \nu_1 > \nu_2$$

i.e., photons of higher frequency will be emitted if transition takes place from  $n = 2$  to 1.



14. (d)  $2E - E = \frac{hc}{\lambda} \Rightarrow E = \frac{hc}{\lambda}$

$$\frac{4E}{3} - E = \frac{hc}{\lambda'} \Rightarrow \frac{E}{3} = \frac{hc}{\lambda'} \therefore \frac{\lambda'}{\lambda} = 3 \Rightarrow \lambda' = 3\lambda$$

15. (d)  $E_n = -13.6 \frac{Z^2}{n^2} \text{ eV}$

Required energy for said transition

$$\Delta E = E_3 - E_1 = 13.6 Z^2 \left[ \frac{1}{1^2} - \frac{1}{3^2} \right]$$

$$\Rightarrow \Delta E = 13.6 \times 3^2 \left[ \frac{8}{9} \right] = 108.8 \text{ eV}$$

$$\Rightarrow \Delta E = 108.8 \times 1.6 \times 10^{-19} \text{ J}$$

$$\text{Now } \Delta E = \frac{hc}{\lambda} = 108.8 \times 1.6 \times 10^{-19}$$

$$\Rightarrow \lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{108.8 \times 1.6 \times 10^{-19}} \\ = 0.11374 \times 10^{-7} \text{ m} = 113.74 \text{ \AA}$$

## DPP 4.2

### Single Correct Answer Type

1. (c) Transition A ( $n = \infty$  to 1): Series limit of Lyman series  
Transition B ( $n = 5$  to  $n = 2$ ): Third spectral line of Balmer series  
Transition C ( $n = 5$  to  $n = 3$ ): Second spectral line of Paschen series

2. (a) D is excitation of electron from the 2<sup>nd</sup> orbit corresponding to absorption line in Balmer series and E is the energy released to bring the electron from  $\infty$  to ground state, i.e., ionisation potential.

3. (c) The wavelength of spectral line in Balmer series is given by
- $$\frac{1}{\lambda} = R \left[ \frac{1}{2^2} - \frac{1}{n^2} \right]$$

For the first line of Balmer series,  $n = 3$

$$\Rightarrow \frac{1}{\lambda_1} = R \left[ \frac{1}{2^2} - \frac{1}{3^2} \right] = \frac{5R}{36}$$

For the second line  $n = 4$

$$\Rightarrow \frac{1}{\lambda_2} = R \left[ \frac{1}{2^2} - \frac{1}{4^2} \right] = \frac{3R}{16}$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \frac{20}{27} \Rightarrow \lambda_1 = \frac{20}{27} \times 6561 = 4860 \text{ \AA}$$

4. (a) We know that  $E_n = -13.6 \frac{Z^2}{n^2} \text{ eV}$  and  $r_n = 0.53 \frac{n^2}{Z} (\text{\AA})$

Here for  $n = 1$ ,  $E_1 = -54.4 \text{ eV}$

$$\text{Therefore } -54.4 = -13.6 \frac{Z^2}{1^2} \Rightarrow Z = 2$$

5. (b) By using  $\frac{1}{\lambda} = RZ^2 \left[ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right]$

$$\text{For hydrogen atom } \frac{1}{(\lambda_{\min})_H} = R \left[ \frac{1}{1^2} - \frac{1}{\infty} \right] = R$$

$$\Rightarrow (\lambda_{\min})_H = \frac{1}{R}$$

$$\text{For hydrogen like atom } \left( \frac{1}{\lambda_{\min}} \right)_{\text{atom}} = RZ^2 \left( \frac{1}{2^2} - \frac{1}{\infty} \right)$$

$$\Rightarrow (\lambda_{\min})_{\text{atom}} = \frac{4}{RZ^2}$$

$$\text{From equations (i) and (ii) } \frac{1}{R} = \frac{4}{RZ^2} \Rightarrow Z = 2$$

6. (b) Transition from  $4E$  to  $E$

$$(4E - E) = \frac{hc}{\lambda_1} \Rightarrow \lambda_1 = \frac{hc}{3E}$$

Transition from  $\frac{7}{3}E$  to  $E$

$$\left( \frac{7}{3}E - E \right) = \frac{hc}{\lambda_2} \Rightarrow \lambda_2 = \frac{3hc}{4E} \quad (i)$$

From equations (i) and (ii)  $\frac{\lambda_1}{\lambda_2} = \frac{4}{9}$

7. (c) The hydrogen atom before the transition was at rest. Therefore from conservation of momentum.

$$p_{H\text{-atom}} = p_{\text{photon}} = \frac{E_{\text{radiated}}}{c} = \frac{13.6 \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{ eV}}{c} \\ 1.6 \times 10^{-27} \times v = \frac{13.6 \left( \frac{1}{1^2} - \frac{1}{5^2} \right) \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

$$\Rightarrow v = 4.352 \text{ m/s} \approx 4 \text{ m/sec}$$

8. (b) Let the energy in A, B and C state be  $E_A$ ,  $E_B$  and  $E_C$ , then from the figure

$$(E_C - E_B) + (E_B - E_A) \\ = (E_C - E_A) \text{ or } \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = \frac{hc}{\lambda_3}$$

$$\Rightarrow \lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$$

9. (d) If E is the energy radiated in transition, then  $E_{R \rightarrow G} > E_{Q \rightarrow S} > E_{R \rightarrow S} > E_{Q \rightarrow R} > E_{P \rightarrow Q}$

For getting blue line energy radiated should be maximum  $\left( E \propto \frac{1}{\lambda} \right)$ . Hence (d) is the correct option.

10. (c) The absorption lines are obtained when the electron jumps from ground state ( $n = 1$ ) to the higher energy states. Thus only 1, 2 and 3 lines will be obtained.

11. (b) Let ground state energy (in eV) be  $E_1$   
Then from the given condition

$$E_{2n} - E_1 = 204 \text{ eV or } \frac{E_1}{4n^2} - E_1 = 204 \text{ eV}$$

$$\Rightarrow E_1 \left( \frac{1}{4n^2} - 1 \right) = 204 \text{ eV} \quad (i)$$

$$\text{and } E_{2n} - E_n = 40.8 \text{ eV}$$

$$\Rightarrow \frac{E_1}{4n^2} - \frac{E_1}{n^2} = E_1 \left( -\frac{3}{4n^2} \right) = 40.8 \text{ eV} \quad (ii)$$

$$\text{From equations (i) and (ii), } \frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \Rightarrow n = 2$$

### Matching Column Type

12. (p-c) (q-b,d) (r-a) (s-b,d)

$$E \propto \frac{1}{n^2},$$

$$V \propto \frac{1}{n} \text{ and } r \propto n^2$$

$$(p) \text{ } Epr \propto \frac{1}{n^2} \times \frac{1}{n} \times n^2 \quad \text{or} \quad Epr \propto \frac{1}{n}$$

- (q)  $\frac{p}{E} \propto \frac{1}{n} \times n^2$  or  $\frac{p}{E} \propto n$   
 (r)  $Er \propto \frac{1}{n^2} \times n^2$  or  $Er$  is independent of  $n$   
 $Er \propto \frac{1}{n^2} \times n^2$  or  $Er, n$   
 (s)  $Pr \propto \frac{1}{n} \times n^2$  or  $pr \propto n$

### Comprehension Type

13. (a)  $\Delta E = 13.6z^2 \left[ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right]$

$$47.2 = 13.6z^2 \left[ \frac{1}{4} - \frac{1}{9} \right]$$

$$47.2 = \frac{13.6z^2 \times 5}{36}$$

$$z^2 = \frac{47.2 \times 36}{13.6 \times 5} \Rightarrow z = 5$$

14. (b)  $E_4 - E_3 = 13.6z^2 \left[ \frac{1}{9} - \frac{1}{16} \right]$

$$= 13.6 \times 25 \times \frac{7}{9 \times 16} = 16.53 \text{ eV}$$

15. (a)  $KE = 13.6 \frac{z^2}{n^2} \text{ eV} = \frac{13.6 \times 25}{(1)^2} = 340 \text{ eV}$

## DPP 4.3

### Single Correct Answer Type

- (a)  $\nu$  varies from 0 to  $\nu_{\max}$ .
- (c) In X-ray spectra, depending on the accelerating voltage and the target element, we may find sharp peaks superimposed on continuous spectrum. These are at different wavelengths for different elements. They form characteristic X-ray spectrum.
- (d) Peaks on the graph represent characteristic X-ray spectrum. Every peak has a certain wavelength, which depends upon the transition of electron inside the atom of the target. While  $\lambda_{\min}$  depends upon the accelerating voltage (As  $\lambda_{\min} \propto 1/V$ ).
- (b)  $\lambda_{\min} = \frac{hc}{eV} \Rightarrow \lambda_1 = \frac{hc}{eV_1}$  and  $\lambda_2 = \frac{hc}{eV_2}$   
 $\therefore \Delta\lambda = \lambda_2 - \lambda_1 = \frac{hc}{e} \left[ \frac{1}{V_2} - \frac{1}{V_1} \right]$ . Given  $V_2 = 1.5 V_1$   
 on solving we get  $V_1 = 16000 \text{ volt} = 16 \text{ kV}$
- (d)  $\Delta\lambda = \lambda_{K\alpha} - \lambda_{\min}$ . When  $V$  is halved  $\lambda_{\min}$  becomes two times but  $\lambda_{K\alpha}$  remains the same.  
 $\therefore \Delta\lambda' = \lambda_{K\alpha} - 2\lambda_{\min} = 2(\Delta\lambda) - \lambda_{K\alpha}$   
 $\therefore \Delta\lambda' < 2(\Delta\lambda)$
- (b) Peak of  $K_{\alpha}$  is greater than peak of  $K_{\beta}$  line.
- (c) According to the energy diagram of X-ray spectra

$$\therefore \Delta E = \frac{hc}{\lambda} \Rightarrow \lambda \propto \frac{1}{\Delta E}$$

( $\Delta E$  = Energy radiated when  $e^-$  jumps from C higher energy orbit to lower energy orbit)

$$\therefore (\Delta E)_{K\beta} > (\Delta E)_{K\alpha} > (\Delta E)_{L\alpha} \therefore \lambda'_{\alpha} > \lambda_{\alpha} > \lambda_{\beta}$$

$$\text{Also } (\Delta E)_{K\beta} = (\Delta E)_{K\alpha} + (\Delta E)_{L\alpha}$$

$$\Rightarrow \frac{hc}{\lambda_{\beta}} = \frac{hc}{\lambda_{\alpha}} + \frac{hc}{\lambda'_{\alpha}} \Rightarrow \frac{1}{\lambda_{\beta}} = \frac{1}{\lambda_{\alpha}} + \frac{1}{\lambda'_{\alpha}}$$

8. (c) By Moseley's law,  $\sqrt{\nu} = a(Z-b)$  or  $\nu = a^2(Z-b)^2$

Comparing with the equation of a parabola,  $y^2 = 4ax$ , it conforms to graph c.

9. (a)  $\lambda_{\min} = \frac{hc}{eV} \Rightarrow \lambda \propto \frac{1}{V}$

$$\therefore \lambda_2 > \lambda_1 \text{ (see graph)} \Rightarrow V_1 > V_2$$

$$\sqrt{\nu} = a(Z-b) \text{ Moseley's law}$$

$$\nu \propto (Z-1)^2 \Rightarrow \lambda \propto \frac{1}{(Z-1)^2} \quad \left( \because \nu \propto \frac{1}{\lambda} \right)$$

$$\lambda_1 > \lambda_2 \text{ (see the graph for characteristic lines)} \Rightarrow Z_2 > Z_1$$

10. (a) The wavelength of  $L_{\alpha}$  line is given by

$$\frac{1}{\lambda} = R(Z-7.4)^2 \left( \frac{1}{2^2} - \frac{1}{3^2} \right) \Rightarrow \lambda \propto \frac{1}{(Z-7.4)^2}$$

$$\Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{(Z_2-7.4)^2}{(Z_1-7.4)^2} \Rightarrow \frac{1.30}{\lambda_2} = \frac{(42-7.4)^2}{(78-7.4)^2} \Rightarrow \lambda_2 = 5.41 \text{ \AA}$$

11. (b)  $\lambda_{K\alpha} \propto \frac{1}{(Z-1)^2} \Rightarrow \frac{\lambda_{Ni}}{\lambda_{Co}} = \left( \frac{Z_{Co}-1}{Z_{Ni}-1} \right)^2 = \left( \frac{27-1}{28-1} \right)^2$

$$\Rightarrow \lambda_{Ni} = \left( \frac{26}{27} \right)^2 \times \lambda_{Co} = \left( \frac{26}{27} \right)^2 \times 179 = 165.9 \text{ pm} < 179 \text{ pm}$$

12. (c)  $\therefore E(K_{\gamma}) > E(K_{\beta}) > E(K_{\alpha}) \Rightarrow \lambda(K_{\gamma}) < \lambda(K_{\beta}) < \lambda(K_{\alpha})$

13. (b) For  $K_{\alpha}$  X-ray line

$$\frac{1}{\lambda_{\alpha}} = R(Z-1)^2 \left[ \frac{1}{1^2} - \frac{1}{2^2} \right] = \frac{3R}{4}(Z-1)^2$$

On putting the given values

$$\frac{1}{0.76 \times 10^{-10}} = \frac{3}{4} \times 1.09 \times 10^7 (Z-1)^2$$

$$\Rightarrow (Z-1)^2 \propto 1600 \Rightarrow Z-1 = 40 \Rightarrow Z = 41$$

14. (c)  $\lambda \propto \frac{1}{(Z-1)^2} \Rightarrow \frac{\lambda_2}{\lambda_1} = \left( \frac{Z_1-1}{Z_2-1} \right)^2$

$$\Rightarrow \frac{\lambda_2}{\lambda} = \left( \frac{43-1}{29-1} \right)^2 = \left( \frac{42}{28} \right)^2 \Rightarrow \lambda_2 = \frac{9}{4} \lambda$$

### Multiple Correct Answers Type

15. (a,d)

$\lambda_m$  decreases on increase of  $V \left( \lambda_m = \frac{12375}{V} \right)$ . Energy of emitted photons will increase as  $\lambda_m$  decreases. Intensity is energy per unit area. Hence, intensity will increase.

# CHAPTER 5

## DPP 5.1

### Single Correct Answer Type

1. (a)  $R = R_0 A^{1/3}$ , where  $R_0 = 1.2 \times 10^{-15}$  m

$$\Rightarrow \log_e R = \log_e R_0 + \frac{1}{3} \log_e A$$

2. (b)  $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$

$$\Rightarrow \frac{3}{5} = \left(\frac{27}{A}\right)^{1/3} \Rightarrow \frac{27}{125} = \frac{27}{A} \Rightarrow A = 125$$

Number of nuclei in atom X =  $A - 52 = 125 - 52 = 73$

3. (c) We have  $r \propto A^{1/3} \Rightarrow \frac{r_2}{r_1} = \left(\frac{A_2}{A_1}\right)^{1/3} = \left(\frac{206}{4}\right)^{1/3}$

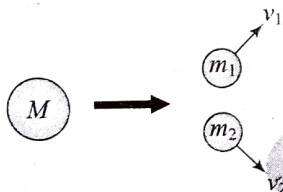
$$\therefore r_2 = 3 \left(\frac{206}{4}\right)^{1/3} = 11.16 \text{ Fermi}$$

4. (a) Electronic configuration of iodine is 2, 8, 18, 18, 7

$$\text{Here } r_n = (0.053 \times 10^{-9} \text{ m}) \frac{n^2}{Z}$$

Here  $n = 5$  and  $Z = 53$ , hence  $r_n = 2.5 \times 10^{-11}$  m

5. (a)



By conservation of momentum  $m_1 v_1 = m_2 v_2$

$$\Rightarrow \frac{v_1}{v_2} = \frac{8}{1} = \frac{m_2}{m_1} \quad (i)$$

$$\text{Also from } r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$$

6. (b) The order of magnitude of mass and volume of uranium nucleus will be

$$m \approx A(1.67 \times 10^{-27} \text{ kg}) \quad (A \text{ is the atomic number})$$

$$V = \frac{4}{3} \pi r^3 \approx \frac{4}{3} \pi [(1.25 \times 10^{-15} \text{ m}) A^{1/3}]^3$$

$$= (8.2 \times 10^{-45} \text{ m}^3) A$$

$$\text{Hence, } \rho = \frac{m}{V} = \frac{A(1.67 \times 10^{-27} \text{ kg})}{(8.2 \times 10^{-45} \text{ m}^3) A}$$

$$\approx 2.0 \times 10^{17} \text{ kg/m}^3$$

7. (d) Suppose closest distance is  $r$ , according to conservation of energy

$$400 \times 10^3 \times 1.6 \times 10^{-19} = 9 \times 10^9 \frac{(ze)(2e)}{r}$$

$$\Rightarrow 6.4 \times 10^{-14} = \frac{9 \times 10^9 \times (82 \times 1.6 \times 10^{-19}) \times (2 \times 1.6 \times 10^{-19})}{r}$$

$$\Rightarrow r = 5.9 \times 10^{-13} \text{ m} = 0.59 \text{ pm}$$

8. (d) The given equation is  ${}_2\text{He}^4 + {}_Z\text{X}^A \rightarrow {}_{Z+2}\text{Y}^{A+3} + A$

Applying charge and mass conservation,

$$4 + A = A + 3 + x \Rightarrow x = 1 \Rightarrow 2 + z = z + 2 + n \Rightarrow n = 0$$

Hence A is a neutron.

9. (d) For stability in the case of lighter nuclei  $\frac{N}{Z} = 1$  and for heavier nuclei  $\frac{N}{Z} > 1$ .

10. (b) Nuclear forces are charge independent.

11. (a) Actual mass of the nucleus is always less than total mass of nucleons so  $M < (NM_n + ZM_p)$ .

12. (a) The mass of nucleus formed is always less than the sum of the masses of the constituent protons and neutrons, i.e.,  $m < (A - Z)m_n + Zm_p$ .

13. (a) Rest energy of an electron =  $m_e c^2$

Here  $m_e = 9.1 \times 10^{-31}$  kg and  $c$  = velocity of light

$$\therefore \text{Rest energy} = 9.1 \times 10^{-31} \times (3 \times 10^8)^2 \text{ joule}$$

$$= \frac{9.1 \times 10^{-31} \times (3 \times 10^8)^2}{1.6 \times 10^{-19}} \text{ eV} = 510 \text{ keV}$$

### Multiple Correct Answers Type

14. (c, d)

Mass of a nucleus is always less than the sum of masses of its constituent particles.

So, mass of  ${}_{10}^{20}\text{Ne}$  nucleus,

$$M_1 < 10(m_p + m_n)$$

Mass defect is more for heavier nucleus.

$$\text{So, } 20(m_n + m_p) - M_2$$

$$> 10(m_n + m_p) - M_1$$

$$M_2 < M_1 + 10(m_n + m_p)$$

But  $M_1 < 10(m_n + m_p)$

Hence,  $M_2 < 2M_1$

15. (c, d)

Options (c) and (d) are correct. Mass number and atomic number are equal in  ${}_1\text{H}^1$ . Mass number may be greater than atomic number (e.g.,  ${}_1\text{H}^2$ )

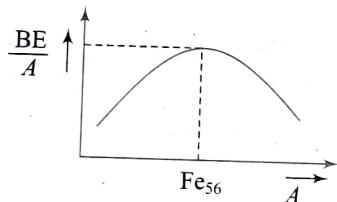
## DPP 5.2

### Single Correct Answer Type

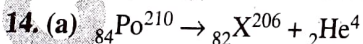
1. (d)  $E = \Delta m \cdot c^2 \Rightarrow E = \frac{0.3}{1000} \times (3 \times 10^8)^2 = 2.7 \times 10^{13} \text{ J}$

$$= \frac{2.7 \times 10^{13}}{3.6 \times 10^6} = 7.5 \times 10^6 \text{ kWh}$$

2. (b) Mass of proton = mass of antiproton  
 $= 1.67 \times 10^{-27} \text{ kg} = 1 \text{ amu}$   
 Energy equivalent to 1 amu = 931 MeV  
 So energy equivalent to 2 amu =  $2 \times 931 \text{ MeV}$   
 $= 1862 \times 10^6 \times 1.6 \times 10^{-19} = 2.97 \times 10^{-10} \text{ J} = 3 \times 10^{-10} \text{ J}$
3. (c) Energy released while forming a nucleus is known as binding energy (by definition).
4. (b)  $Q = 4(x_2 - x_1)$
5. (b) The elements high on the BE versus mass number plot are very tightly bound and, hence, are stable. And those elements that are lower on this plot, are less tightly bound and, hence, are unstable.  
 Since helium nucleus shows a peak on this plot, so it is very stable.
6. (c) Energy is released in a process when total binding energy (BE) of the nucleus is increased or we can say when total BE of products is more than the reactants. By calculation we can see that only in case of option (c), this happens.  
 Given  $W \rightarrow 2Y$   
 BE of reactants =  $120 \times 75 = 900 \text{ MeV}$   
 and BE of products =  $2 \times (60 \times 85) = 1020 \text{ MeV}$   
 i.e., BE of products > BE of reactants.
7. (b) Binding energy per nucleon increases with atomic number and is maximum for iron. After that it decreases.



8. (a)  $BE = \Delta mc^2 = [2(1.0087 + 1.0073) - 4.0015] = 28.4 \text{ MeV}$
9. (b)  $\frac{\text{Binding energy}}{\text{Nucleon}} = \frac{0.0303 \times 931}{4} \approx 7$
10. (c)  $B = [ZM_p + NM_n - M(N, Z)]c^2$   
 $\Rightarrow M(M, Z) = ZM_p + NM_n - B/c^2$
11. (c) Mass of  ${}_1\text{H}^2 = 2.01478 \text{ a.m.u.}$   
 Mass of  ${}_2\text{He}^4 = 4.00388 \text{ a.m.u.}$   
 Mass of two deuterium  $2 \times 2.01478 = 4.02956$   
 Energy equivalent to  ${}_1\text{H}^2$   
 $= 4.02956 \times 1.112 \text{ MeV} = 4.48 \text{ MeV}$   
 Energy equivalent to  ${}_2\text{He}^4$   
 $= 4.00388 \times 7.047 \text{ MeV} = 28.21 \text{ MeV}$   
 Energy released  $28.21 - 4.48 = 23.73 \text{ MeV} = 24 \text{ MeV}$
12. (d) B.E. of  $\text{Li}^7 = 39.20 \text{ MeV}$  and  $\text{He}^4 = 28.24 \text{ MeV}$   
 Hence binding energy of  ${}_2\text{He}^4 = 56.48 \text{ MeV}$   
 Energy of reaction  $= 56.48 - 39.20 = 17.28 \text{ MeV}$
13. (b)  ${}_1\text{H}^2 + {}_1\text{H}^2 \rightarrow {}_2\text{He}^4 + \text{energy}$   
 Binding energy of a ( ${}_1\text{H}^2$ ) deuterium nuclei  
 $= 2 \times 1.1 = 2.2 \text{ MeV}$   
 Total binding energy of two deuterium nuclei  
 $= 2.2 \times 2 = 4.4 \text{ MeV}$   
 Binding energy of a ( ${}_2\text{He}^4$ ) nuclei  $= 4 \times 7 = 28 \text{ MeV}$   
 So, energy released in fusion  $= 28 - 4.4 = 23.6 \text{ MeV}$



Using conservation of linear momentum

$$206v' + 4v = 0 \Rightarrow v' = -\frac{4v}{206} \Rightarrow |v'| = \frac{4v}{206}$$

15. (c) The equation is  $\text{O}^{17} \rightarrow {}_0\text{n}^1 + \text{O}^{16}$   
 $\therefore$  Energy required = B.E. of  $\text{O}^{17}$  - B.E. of  $\text{O}^{16}$   
 $= 17 \times 7.75 - 16 \times 7.97 = 4.23 \text{ MeV}$

## DPP 5.3

### Single Correct Answer Type

1. (d)  ${}_{92}\text{U}^{238} \rightarrow {}_2\text{He}^4 + {}_{90}\text{X}^{234} \rightarrow {}_{-1}\text{e}^0 + {}_{91}\text{U}^{234}$   
 Hence,  $A = 234, Z = 91$
2. (b)  ${}_Z\text{X}^A \xrightarrow{-1\beta^0} {}_{Z+1}\text{Y}^A \xrightarrow{2\text{He}^4(\alpha)} {}_{Z-1}\text{K}^{A-4}$   
 $\xrightarrow{-2\gamma^0} {}_{Z-1}\text{K}^{A-4}$
3. (a)  ${}_{72}\text{A}^{180} \xrightarrow{\alpha} {}_{70}\text{A}_1^{176} \xrightarrow{\beta} {}_{71}\text{A}_2^{176} \xrightarrow{\alpha} {}_{69}\text{A}_3^{174} \xrightarrow{\gamma} {}_{69}\text{A}_4^{172}$
4. (a)  $\alpha$  decay decreases the mass number by 4 and atomic number by 2.  $\beta$  decay increases the atomic number by 1. Here atomic number of C is the same as that of A.
5. (c) For 80 minutes, number of half-lives of sample A  $= n_A = \frac{80}{20}$   
 $= 4$  and number of half-lives of sample B  $= n_B = \frac{80}{40} = 2$ . Also  
 by using  $N = N_0 \left(\frac{1}{2}\right)^n$   
 $\Rightarrow N \propto \frac{1}{2^n} \Rightarrow \frac{N_A}{N_B} = \frac{2^{n_B}}{2^{n_A}} = \frac{2^2}{2^4} = \frac{1}{4}$
6. (d) Number of nuclei decreases exponentially  
 $N = N_0 e^{-\lambda t}$  and rate of decay  $\left(-\frac{dN}{dt}\right) = \lambda N$   
 Therefore, decay process losses up to  $t = \infty$ .  
 Therefore, a given nucleus may decay at any time after  $t = 0$ .
7. (a) Number of half-lives in two days for substances 1 and 2 respectively are  $n_1 = \frac{2 \times 24}{12} = 4$  and  $n_2 = \frac{2 \times 24}{1.6} = 3$   
 By using  $N = N_0 \left(\frac{1}{2}\right)^n \Rightarrow \frac{N_1}{N_2} = \frac{(N_0)_1}{(N_0)_2} \times \frac{\left(\frac{1}{2}\right)^{n_1}}{\left(\frac{1}{2}\right)^{n_2}}$   
 $= \frac{2}{1} \times \frac{\left(\frac{1}{2}\right)^4}{\left(\frac{1}{2}\right)^3} = \frac{1}{2}$
8. (c) By using  $N = N_0 e^{-\lambda t}$  and average life time  $\tau = \frac{1}{\lambda}$   
 So  $N = N_0 e^{-\lambda \times 1/\lambda} = N_0 e^{-1} \Rightarrow \frac{N}{N_0} = e^{-1} = \frac{1}{e}$   
 Now disintegrated fraction  $= 1 - \frac{N}{N_0} = 1 - \frac{1}{e} = \frac{e-1}{e}$
9. (c)  $A = A_0 e^{-\lambda t} = A_0 e^{-t/T}$ , where  $T$  = mean life  
 So  $A_1 = A_0 e^{-t_1/T} \Rightarrow A_0 = \frac{A_1}{e^{-t_1/T}} = A_1 e^{t_1/T}$   
 $\therefore A_2 = A_0 e^{-t_2/T} = (A_1 e^{t_1/T}) e^{-t_2/T} \Rightarrow A_2 = A_1 e^{(t_1 - t_2)/T}$

$$10. (b) N = N_0 \left( \frac{1}{2} \right)^{\frac{t}{T_{1/2}}}$$

$$\text{No. of atoms at } t = 2\text{hr}, N_1 = 8 \times 10^{10} \left( \frac{1}{2} \right)^{\frac{2}{1}} = 2 \times 10^{10}$$

$$\text{No. of atoms at } t = 4\text{hr}, N_2 = 8 \times 10^{10} \left( \frac{1}{2} \right)^{\frac{4}{1}} = \frac{1}{2} \times 10^{10}$$

$\therefore$  No. of atoms decayed in given duration

$$= \left( 2 - \frac{1}{2} \right) \times 10^{10} = 1.5 \times 10^{10}$$

$$11. (b) n_\alpha = \frac{A - A'}{4} = \frac{232 - 208}{4} = 6$$

$$\text{and } n_\beta = (2n_\alpha - Z + Z') = (2 \times 6 - 90 + 82) = 4$$

12. (a) Remaining amount

$$= 16 \times \left( \frac{1}{2} \right)^{32/2} = 16 \times \left( \frac{1}{2} \right)^{16} = \left( \frac{1}{2} \right)^{12} < 1 \text{ mg}$$

$$13. (c) \frac{N}{N_0} = \left( \frac{1}{2} \right)^{15/5} = \frac{1}{8} \Rightarrow \text{Decayed fraction} = 1 - \frac{1}{8} = \frac{7}{8}$$

$$14. (c) \text{ By using } n_\alpha = \frac{A - A'}{4} \text{ and } n_\beta = 2n_\alpha - Z + Z'$$

$$\Rightarrow A' = A - 4n_\alpha = 236 - 4 \times 3 = 224$$

$$\text{and } Z' = (n_\beta - 2n_\alpha + Z) = (1 - 2 \times 3 + 88) = 83$$

15. (d) In the given case, 12 days = 3 half-lives. Number of atoms left after 3 half-lives.

$$= 6.4 \times 10^{10} \times \frac{1}{2^3} = 0.8 \times 10^{10}$$

## DPP 5.4

### Single Correct Answer Type

$$1. (b) N = N_0 e^{-\lambda t}$$

$$\therefore 0.9N_0 = N_0 e^{-\lambda \times 5} \Rightarrow 5\lambda = \log_e \frac{1}{0.9} \quad (i)$$

$$\text{and } xN_0 = N_0 e^{-\lambda \times 20} \Rightarrow 20\lambda = \log_e \left( \frac{1}{x} \right) \quad (ii)$$

Dividing (i) by (ii), we get

$$\frac{1}{4} = \frac{\log_e(1/0.9)}{\log_e(1/x)} = \frac{\log_{10}(1/0.9)}{\log_{10}(1/x)} = \frac{\log_{10} 0.9}{\log_{10} x}$$

$$\Rightarrow \log_{10} x = 4 \log_{10} 0.9 \Rightarrow x = 0.658 = 65.8\%$$

2. (c) If in the rock there is no Y element, then the time taken by element X to reduce to  $\frac{1}{8}$ th the initial value will be equal to

$$\frac{1}{8} = \left( \frac{1}{2} \right)^n \text{ or } n = 3$$

Therefore, from the beginning three half-lives time is spent. Hence the age of the rock is  $= 3 \times 1.37 \times 10^9 = 4.11 \times 10^9$  years

$$3. (a) \frac{dN}{dt} = \lambda N; \lambda = \frac{0.6931}{t_{1/2}} = \frac{0.6931}{1620 \times 365 \times 24 \times 60 \times 60}$$

$$N = \frac{6.023 \times 10^{23}}{226}$$

$$\therefore \frac{dN}{dt} = \frac{0.6931 \times 6.023 \times 10^{23}}{1620 \times 365 \times 24 \times 60 \times 60 \times 226} = 3.61 \times 10^{10}$$

(Avogadro's number  $N = 6.02 \times 10^{26}$  atom/kilomol)

$$4. (a) \lambda = \lambda_1 + \lambda_2 \Rightarrow \frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2}$$

$$\therefore T = \frac{T_1 T_2}{T_1 + T_2} = \frac{810 \times 1620}{810 + 1620} = 540 \text{ years}$$

Hence  $\frac{1}{4}$ th of material remains after 1080 years.

$$5. (c) \lambda_\alpha = \frac{1}{1620} \text{ per year and } \lambda_\beta = \frac{1}{405} \text{ per year and it is given that}$$

$$\text{the fraction of the remained activity } \frac{A}{A_0} = \frac{1}{4}$$

Total decay constant

$$\lambda = \lambda_\alpha + \lambda_\beta = \frac{1}{1620} + \frac{1}{405} = \frac{1}{324} \text{ per year}$$

$$\text{We know that } A = A_0 e^{-\lambda t} \Rightarrow t = \frac{1}{\lambda} \log_e \frac{A_0}{A}$$

$$\Rightarrow t = \frac{1}{\lambda} \log_e 4 = \frac{2}{\lambda} \log_e 2 = 324 \times 2 \times 0.693 = 449 \text{ years}$$

$$6. (a) \text{ Rest } \xrightarrow{\quad} \text{ } \xrightarrow{\quad} \text{ } + \text{ } \xrightarrow{\quad}$$

According to the conservation of momentum

$$4v = (A - 4)v' \Rightarrow v' = \frac{4v}{A - 4}$$

$$7. (b) \lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{20} = 0.03465$$

$$\text{Now time of decay } t = \frac{2.303}{\lambda} \log \frac{N_0}{N}$$

$$\Rightarrow t_1 = \frac{2.303}{0.03465} \log \frac{100}{67} = 11.6 \text{ min}$$

$$\text{and } t_2 = \frac{2.303}{0.03465} \log \frac{100}{33} = 32 \text{ min}$$

Thus time difference between points of time

$$= t_1 - t_2 = 32 - 11.6 = 20.4 \text{ min} \approx 20 \text{ min}$$

$$8. (a) N = N_0 \left( \frac{1}{2} \right)^{t/T_{1/2}} \Rightarrow N_A = 10 \left( \frac{1}{2} \right)^{t/1} \text{ and } N_B = 1 \left( \frac{1}{2} \right)^{t/2}$$

$$\text{Given } N_A = N_B \Rightarrow 10 \left( \frac{1}{2} \right)^t = \left( \frac{1}{2} \right)^{t/2}$$

$$\Rightarrow 10 = \left( \frac{1}{2} \right)^{-t/2} \Rightarrow 10 = 2^{t/2}. \text{ Taking log both the sides}$$

$$\log_{10} 10 = \frac{t}{2} \log_{10} 2 \Rightarrow 1 = \frac{t}{2} \times 0.3010$$

$$\Rightarrow t = 6.62 \text{ years}$$

9. (b) Here  $T_{1/2} = 20$  minutes, we know  $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}}$

For 20% decay:  $\frac{N}{N_0} = \frac{80}{100} = \left(\frac{1}{2}\right)^{t/20}$

For 80% decay:  $\frac{N}{N_0} = \frac{20}{100} = \left(\frac{1}{2}\right)^{t/20}$

Dividing (ii) by (i)

$$\frac{1}{4} = \left(\frac{1}{2}\right)^{\frac{(t_2 - t_1)}{20}}$$

On solving we get  $t_2 - t_1 = 40$  min

10. (a) Excitation energy  $\Delta E = E_2 - E_1 = 13.6 Z^2 \left[ \frac{1}{1^2} - \frac{1}{2^2} \right]$

$$\Rightarrow 40.8 = 13.6 \times \frac{3}{4} \times Z^2 \Rightarrow Z = 2$$

Now required energy to remove the electron from the ground

$$\text{state} = \frac{+13.6 Z^2}{(1)^2} = 13.6(Z)^2 = 54.4 \text{ eV}$$

11. (b) Rate of disintegration  $\frac{dN}{dt} = 10^{17} \text{ s}^{-1}$

Half-life  $T_{1/2} = 1445$  years

$$= 1445 \times 365 \times 24 \times 60 \times 60 = 4.55 \times 10^{10} \text{ sec}$$

Now decay constant

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{4.55 \times 10^{10}} = 1.5 \times 10^{-11} \text{ per sec}$$

The rate of disintegration

$$\frac{dN}{dt} = \lambda \times N_0 \Rightarrow 10^{17} = 1.5 \times 10^{-11} \times N_0$$

$$\Rightarrow N_0 = 6.6 \times 10^{27}$$

12. (a)  $R_0 = \text{Initial activity} = 1 \text{ microcurie} = 3.7 \times 10^4 \text{ dps}$

$r = \text{Activity in } 1 \text{ cm}^3 \text{ of blood at } t = 5 \text{ hrs}$

$$= \frac{296}{60} \text{ dps} = 4.93 \text{ dps}$$

$R = \text{Activity of whole blood at time } t = 5 \text{ hr.}$

$$\text{Total volume should be } V = \frac{R}{r} = \frac{R_0 e^{-\lambda t}}{r}$$

$$= \frac{3.7 \times 10^4 \times 0.7927}{4.93} = 5.94 \times 10^3 \text{ cm}^3 = 5.94 \text{ L}$$

13. (b) Here  $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{1/3}$

where  $n = \text{Number of half-lives} = \frac{1}{3}$

$$\Rightarrow \frac{N}{N_0} = \frac{1}{1.26} \Rightarrow \frac{N_U}{N_{Pb} + N_U} = \frac{1}{1.26}$$

$$\Rightarrow N_{Pb} = 0.26 N_U \Rightarrow \frac{N_{Pb}}{N_U} = 0.26$$

14. (a) Activity of substance that has 2000 disintegration/sec

$$= \frac{2000}{3.7 \times 10^{10}} = 0.054 \times 10^{-6} \text{ ci} = 0.054 \mu\text{ci}$$

The number of radioactive nuclei having activity  $A$

$$N = \frac{A}{\lambda} = \frac{2000 \times T_{1/2}}{\log_e 2}$$

$$= \frac{2000 \times 138.6 \times 24 \times 3600}{0.693} = 3.45 \times 10^{10}$$

15. (c) 1 week  $\approx 7$  days  $= 7 \times 24 \text{ hrs} = 14$  half-lives

$$\text{Number of atoms left} = \frac{N_0}{(2)^{14}}$$

$$\text{Activity} = N\lambda$$

$$\therefore \text{Activity left is } \frac{1}{(2)^{14}} \text{ times the initial}$$

$$\Rightarrow \frac{1}{(2)^{14}} \times 1 \text{ curie} = \frac{1}{16384} \times 1 \text{ curie} \approx 61 \times 10^{-6} \text{ curie} \approx 60 \mu\text{ci}$$

## DPP 5.5

### Single Correct Answer Type

1. (d) Energy/day  $= 200 \times 10^6 \times 24 \times 3600$   
 $= 2 \times 2.4 \times 3.6 \times 10^{12} = 1728 \times 10^6 \text{ J}$

2. (c) Power  $= 1000 \text{ kW} = 10^6 \text{ J/s}$

$$\text{Rate of nuclear fission} = \frac{10^6}{200 \times 1.6 \times 10^{-13}} = 3.125 \times 10^{16}$$

3. (a)  $P = n \left( \frac{E}{t} \right) \Rightarrow 1000 = \frac{n \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{t}$

$$\Rightarrow \frac{n}{t} = 3.125 \times 10^{13}$$

4. (b)  $\frac{\text{Energy}}{\text{Fission}} = 200 \text{ MeV} = 200 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$

$$\text{Fission rate} = \frac{5}{200 \text{ MeV}} = 1.56 \times 10^{11} \text{ fission/sec}$$

5. (b) Mass of proton  $= \text{mass of antiproton}$

$$= 1.67 \times 10^{-27} \text{ kg} = 1 \text{ amu}$$

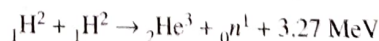
$$\text{Energy equivalent to } 1 \text{ amu} = 931 \text{ MeV}$$

$$\text{So energy equivalent to } 2 \text{ amu} = 2 \times 931 \text{ MeV}$$

$$= 1862 \times 10^6 \times 1.6 \times 10^{-19} = 2.97 \times 10^{-10} \text{ J}$$

$$= 3 \times 10^{-10} \text{ J}$$

6. (a) Fusion reaction of deuterium is



$$\text{So } E = \frac{6.02 \times 10^{23} \times 10^3 \times 3.27 \times 1.6 \times 10^{-13}}{2 \times 2} = 7.8 \times 10^{13} \text{ J}$$

$$= 8 \times 10^{13} \text{ J}$$

7. (d) Energy released in the fission of one nucleus  $= 200 \text{ MeV}$

$$= 200 \times 10^6 \times 1.6 \times 10^{-19} \text{ J} = 3.2 \times 10^{-11} \text{ J}$$

$$P = 16 \text{ kW} = 16 \times 10^3 \text{ W}$$

Now, the number of nuclei required per second

$$n = \frac{P}{E} = \frac{16 \times 10^3}{3.2 \times 10^{-11}} = 5 \times 10^{14}$$

8. (a) Number of fissions per second

$$= \frac{\text{Power output}}{\text{Energy released per fission}}$$

$$= \frac{3.2 \times 10^6}{200 \times 10^6 \times 1.6 \times 10^{-19}} = 1 \times 10^{17}$$

$$\Rightarrow \text{Number of fission per minute} = 60 \times 10^{17} = 6 \times 10^{18}$$

9. (b)  ${}_1\text{H}^2 + {}_1\text{H}^2 \rightarrow {}_2\text{He}^4 + \text{energy}$

Binding energy of a ( ${}_1\text{H}^2$ ) deuterium nuclei

$$= 2 \times 1.1 = 2.2 \text{ MeV}$$

Total binding energy of two deuterium nuclei

$$= 2.2 \times 2 = 4.4 \text{ MeV}$$

Binding energy of a ( ${}_2\text{He}^4$ ) nuclei =  $4 \times 7 = 28 \text{ MeV}$

So, energy released in fusion =  $28 - 4.4 = 23.6 \text{ MeV}$

10. (c) Mass of a uranium nucleus

$$92 \times 1.6725 \times 10^{-27} + 143 \times 1.6747 \times 10^{-27}$$

$$= 393.35 \times 10^{-27} \text{ kg}$$

Number of nuclei in the given mass

$$= \frac{1}{393.35 \times 10^{-27}} = 2.542 \times 10^{24}$$

Energy released =  $200 \times 2.542 \times 10^{24} \text{ MeV}$

$$= 5.08 \times 10^{26} \text{ MeV} = 8.135 \times 10^{13} \text{ J} = 8.2 \times 10^{13} \text{ J}$$

11. (a) Total mass of reactants

$$= (2.0141) \times 2 = 4.0282 \text{ amu}$$

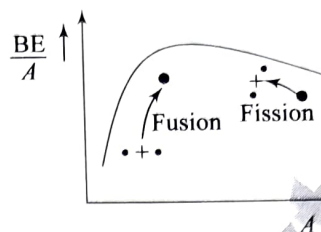
Total mass of products = 4.0024 amu

Mass defect =  $4.0282 \text{ amu} - 4.0024 \text{ amu}$

$$= 0.0258 \text{ amu}$$

$$\therefore \text{Energy released } E = 931 \times 0.0258 = 24 \text{ MeV}$$

12. (b)



$$13. (b) P = \frac{nE}{t} \Rightarrow 300 \times 10^6 = \frac{n \times 170 \times 10^6 \times 1.6 \times 10^{-19}}{t}$$

$$\therefore \text{Number of atoms per sec } \frac{n}{t} = 1.102 \times 10^{19}$$

$$\text{Number of atoms per hour} = 1.02 \times 10^{19} \times 3600 = 3.97 \times 10^{22}$$

### Multiple Correct Answers Type

14. (a, d)

Two or more lighter nuclei are combined to form a relatively heavy nucleus to release the energy.

### Matching Column Type

15. Energy is released in all the reactions. So, mass of the products formed is less than the original mass of the system. As the energy is released in beta decay, binding energy per nucleon increases. Mass number and charge remain conserved in all nucleus reactions.